WASTE MANAGEMENT AND RESOURCE CONSUMPTION

Throw Away Society
Content of the Solid Waste Stream
The Three Rs
Compost, Landfills and Incineration
Hazardous Waste Disposal

Throw Away Society

Throw Away Society

- Humans generate waste that other organisms cannot use
- In the 1900's everything was essential recycled
  - A broken bookshelf was turned into a step stool, once that was broken, the would was burned for heat within the household
- After WWII consumption patterns changed
  - It was now possible to purchase "labor saving", household conveniences that could be used and then thrown away these
  - The typical characteristic of these types of items is Planned obsolescence→ the design on a product so that it will need to be replaced within a few years

Throw Away Society

- TV dinners, disposable napkins, disposable plates and forks became the norm
- In 1960 disposable diapers replaced reusable cloth diapers
- Components of household items changed as well
  - They contained mixtures of different materials making it harder to repurpose or to recycle.
- The U.S. became the leader of what came to be known as the "throw away society"

Content of the Solid Waste Stream

- Types of waste:
  - Solid Waste: any unwanted or discarded material we produce that is not a liquid or gas.
    - Municipal Solid Waste (MSW)- produce directly from homes.
    - Industrial Solid Waste- produced indirectly by industries that supply people with goods and services (industrial, agricultural, mining, etc)
  - Hazardous: threatens human health or the environment because it is toxic, chemically active, corrosive or flammable.

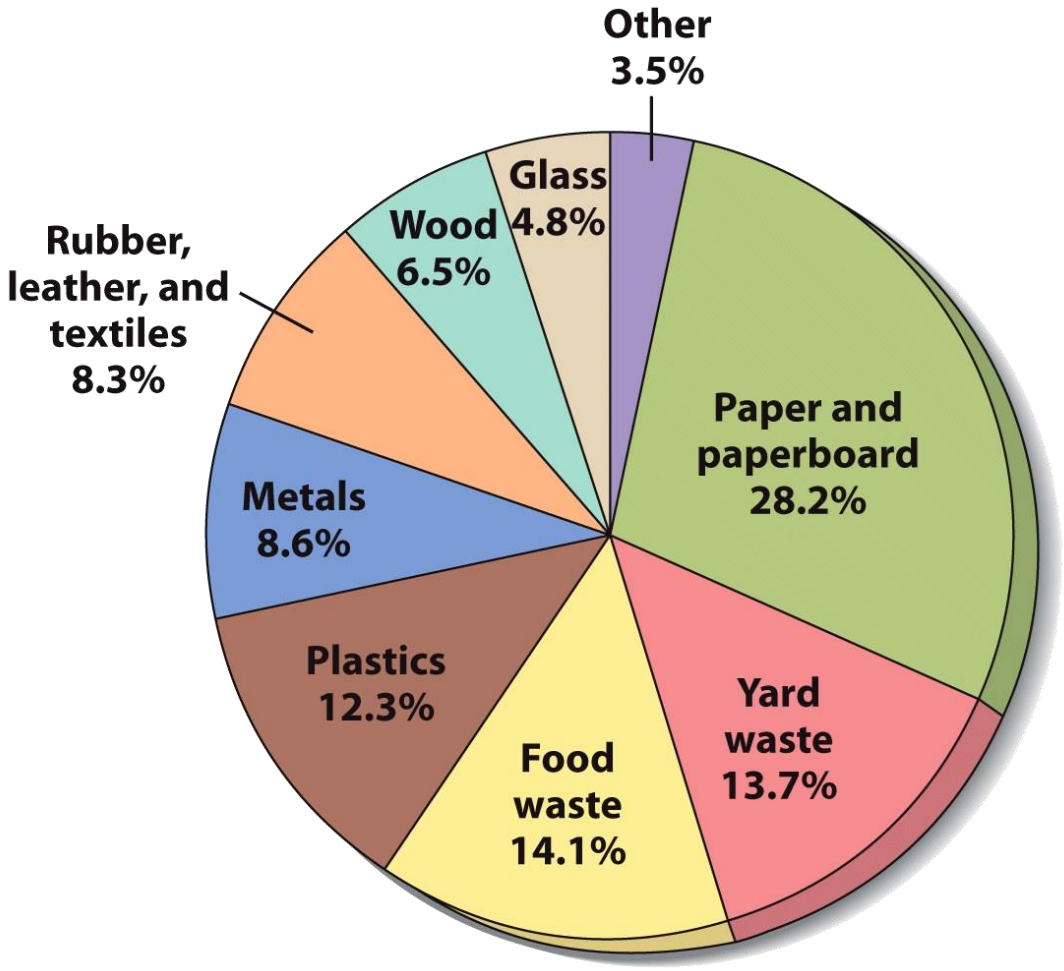
WASTING RESOURCES

- Waste generation is highest in developed countries
  - Instead of repairing items, they are replaced
- The United States produces about a third of the world's solid waste and buries more than half of it in landfills.
  - More waste per capita than any other country
  - 1.98kg (4.34lb) per person per day
  - 243 million tons in 2009 (down from 2007)
  - About 98.5% is industrial solid waste.
  - The remaining 1.5% is MSW.
    - About 55% of U.S. MSW is dumped into landfills, 30% is recycled or composted, and 15% is burned in incinerators.

Where does that trash go?

Content of the Solid Waste Stream

- Components of Municipal Solid Waste
- EPA estimates that:
  - 60% comes from residences
  - 40% commercial and institutional facilities



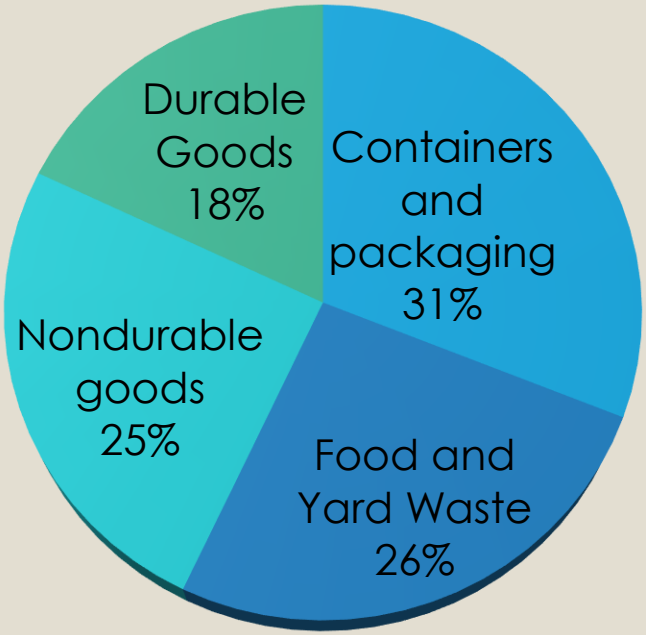
Content of the Solid Waste Stream

- In 2008 the average person generated 4.5 pounds of waste per day
- In Japan, each person generates 2.4 pounds of waste each day
- Waste generation varies by season, socioeconomic status and geographic location within the country

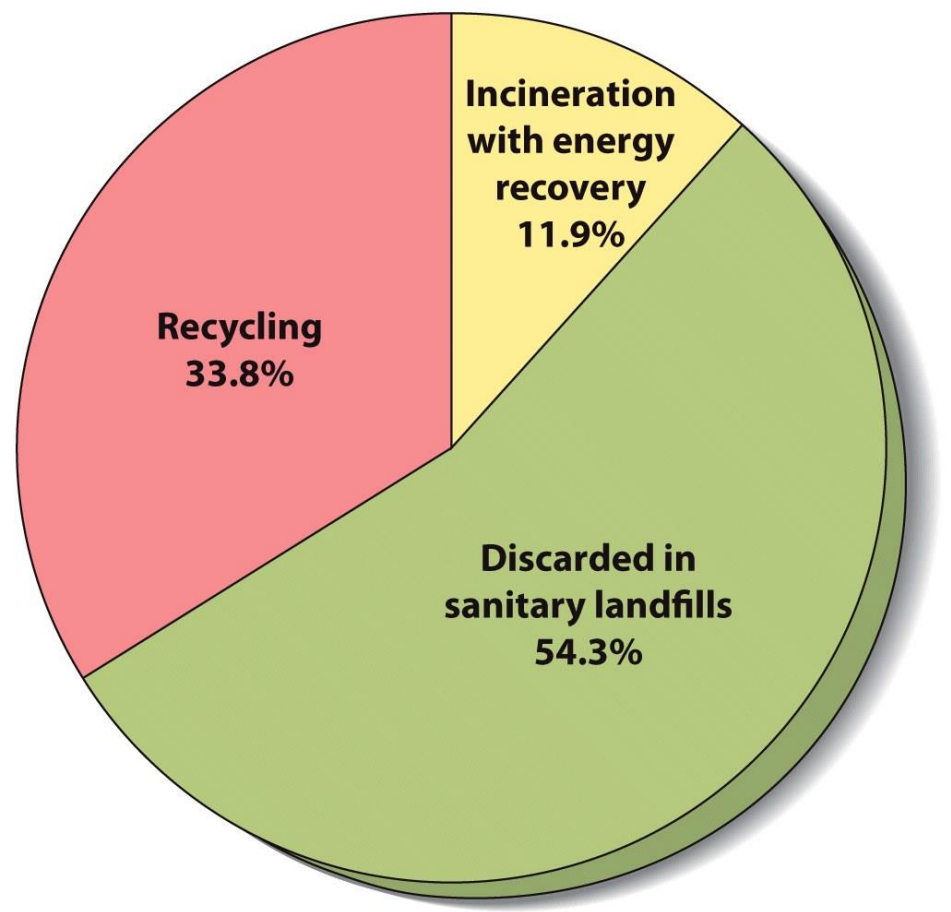
Content of the Solid Waste Stream

- Waste stream- the flow of solid waste that is recycled, incinerated, placed in a solid waste landfill or disposed of in another way

Breakdown of MSW by Source



The Fate of MSW



Factors Contributing to Increasing Amounts of MSW

- Increasing populations
- Changing lifestyles
- Disposable materials*
- Excessive packaging*

*** = two largest contributors to waste volume**

Content of the Solid Waste Stream

- E-waste: A Growing Problem
- E-waste consists of toxic and hazardous waste such as PVC, lead, mercury, and cadmium.
- The U.S. produces almost half of the world's e-waste but only recycles about 10% of it.

Figure 22-4

E-waste

- Over 2 billions electronic devices have been sold in the US since 1980.
- Of these:
  - ½ are being used (or reused)
  - 9% is in storage
  - 40% has been disposed of
- US households discarded 304 million electronic devices in 2005- 2/3rds still in working condition

Industrial Solid Waste

- Industrial Solid Waste- solid waste that is considered neither MSW nor hazardous waste
  - Waste from factories, mining activities, agriculture, petroleum extraction etc
- About 7.6 billion tons of waste
  - 97% is wastewater
  - 228 million tons of solid waste are generated by 60,000 facilities each year
- Industrial ecologists examine the entire life cycle of a given product to make it more ecologically efficient (life-cycle analysis)
  - Origins in raw material – manufacturing – its use – and its disposal

Industrial Solid Waste

- Sometimes it is cheaper to generate waste than to avoid generating waste
- Because our market system awards only economic efficiency, all too often industry has no financial incentive to achieve physical efficiency

Industrial Solid Waste

- American Airlines in DFW recycled enough aluminum cans and white paper in 5 years to save $205,000
- They recycled 3,000 broken baggage containers into lawn furniture
- A program to gather suggestions from employees brought 700 ideas to reduce waste and 15 of those saved the company over $8 million the first year

Diverting materials from the Waste Stream

- In the 90's United States Citizens began promoting the idea of diverting materials from the waste stream with the popular phrase "Reduce, Reuse, Recycle" or "The 3 Rs"
- Add in 2 more R's- Refuse and Repurpose
- We can manage the solid wastes we produce and reduce or prevent their production
  - Integrated Waste Management

Solutions to the Solid-Waste Problem

Three main components of waste management:

- Minimizing the amount of waste we generate (source reduction)
- Recovering waste materials and finding ways to recycle them
- Disposing of waste safely and effectively

INTEGRATED WASTE MANAGEMENT

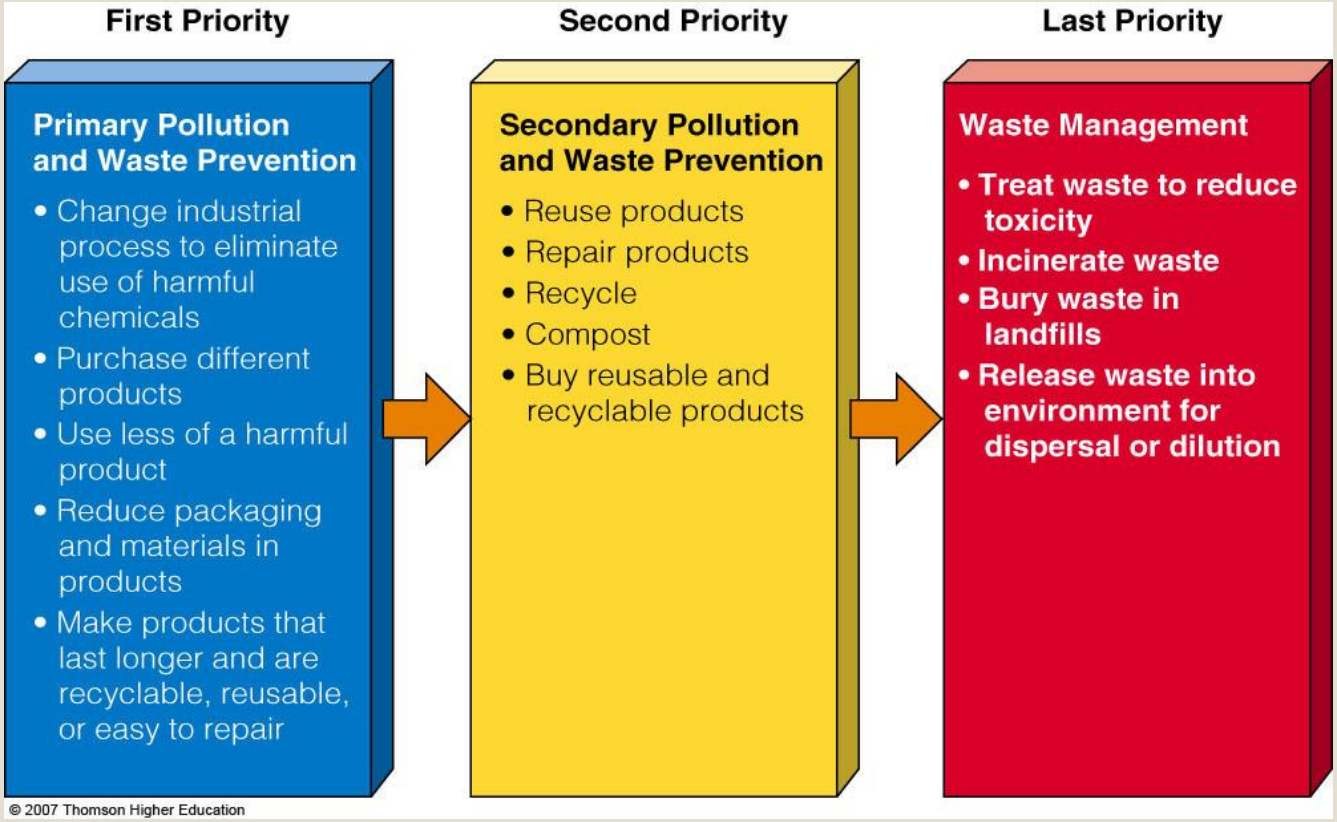


Figure 22-5

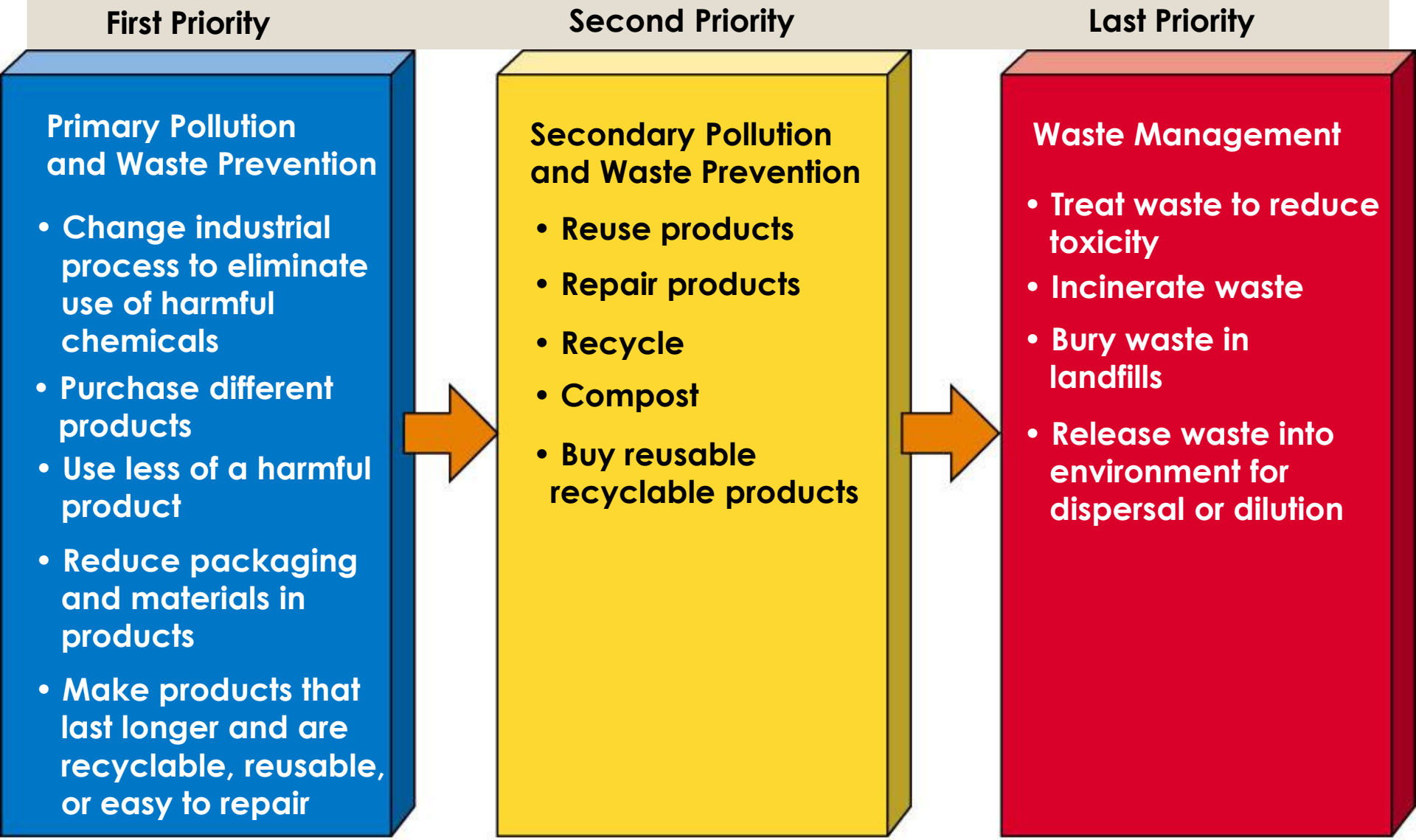
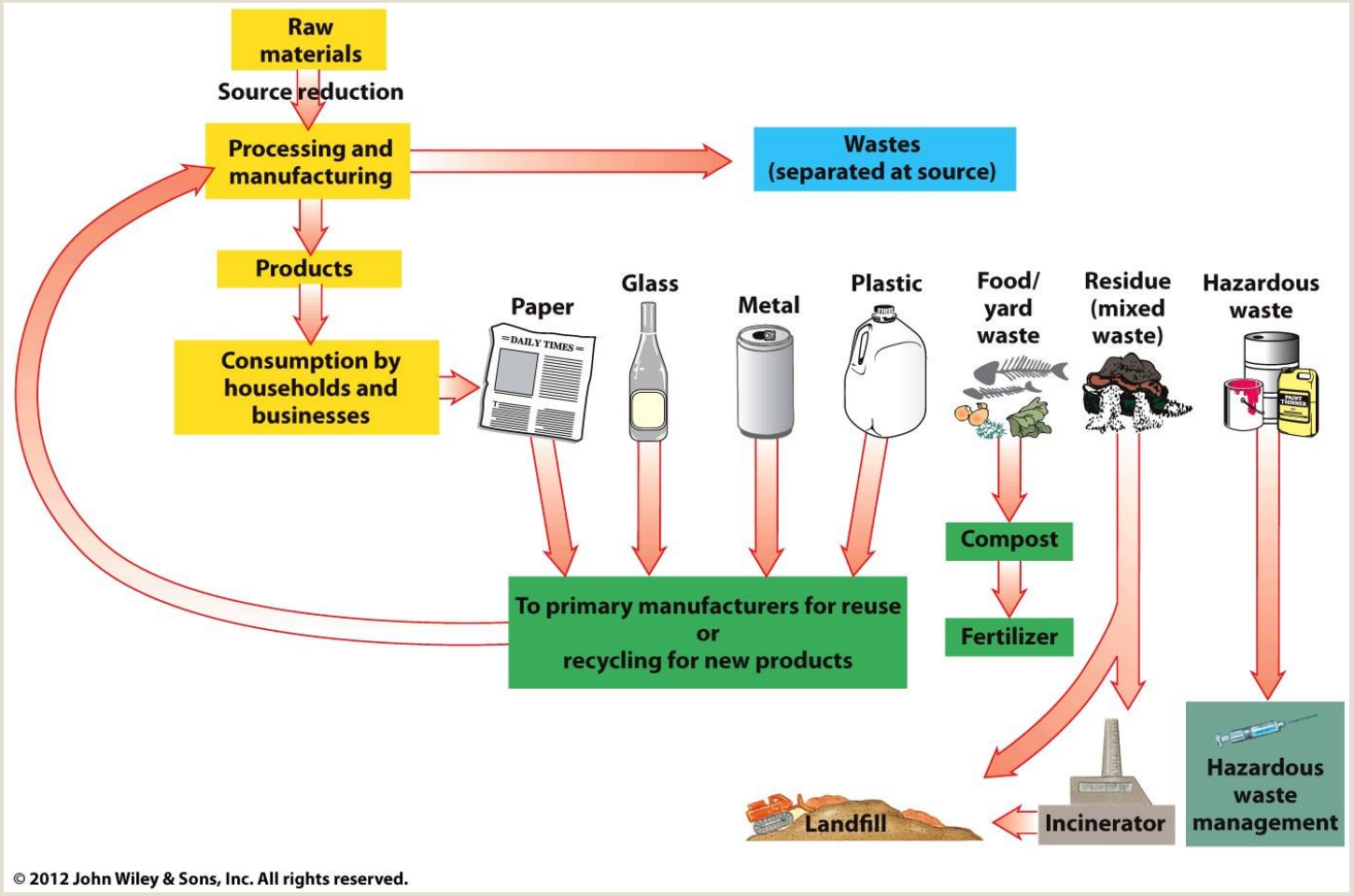


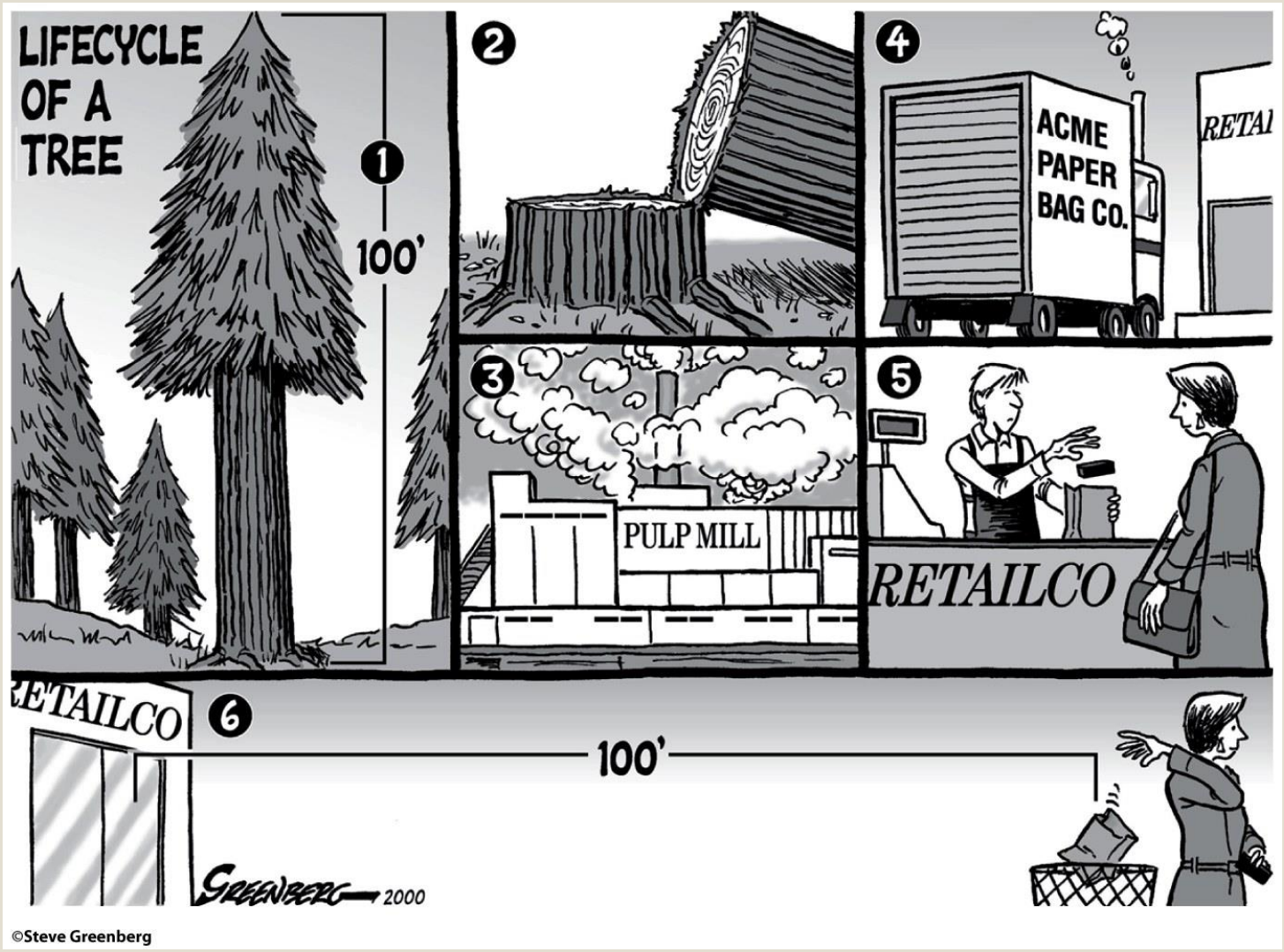
Fig. 22-5, p. 523

Integrated Waste Management



Solutions: Reducing Solid Waste

- ***Refuse***: to buy items that we really don't need or items with extraneous packaging
- ***Reduce***: consume less and live a simpler and less stressful life by practicing simplicity.
- ***Reuse***: rely more on items that can be used over and over.
- ***Repurpose***: use something for another purpose instead of throwing it away.
- ***Recycle***: paper, glass, cans, plastics…and buy items made from recycled materials.


LIFECYCLE OF A TREE
1
100'
2
3
PULP MILL
4
ACME PAPER BAG CO.
RETAI
5
RETAILCO
RETAILCO
6
100'
GREENBERG 2000
©Steve Greenberg

Refuse

- Source Reduction- seeks to reduce waste by reducing, in the early stages of design and manufacture, the use of materials- toxic and otherwise- destined to become MSW
- In most cases, source reduction will increase energy efficiency because it produces less waste to begin with, avoiding disposal processes.
- Can be economical- think of CD packaging
  - Used to be packages in large plastic sleeves that were three times the size of the CD in plastic jewel cases
  - Now most are wrapped with small plastic material that just covers the paper/cardboard CD case
  - Most music can be downloaded instead

How and Why to Refuse

- Why-
  - Less weight
  - Expends less energy
  - Cheaper than paying for all the packing
- How
  - Internet information transfer vs printed material
  - Resale and donation of durable goods
  - Lengthening a product's life- no need to buy more
  - Refusing bulk mail

REUSE

- Reusing products is an important way to reduce resource use, waste, and pollution in developed countries.
- Reusing can be hazardous in developing countries for poor who scavenge in open dumps.
  - They can be exposed to toxins or infectious diseases.

How People Reuse Materials

- Children looking for materials to sell in an open dump near Manila in the Philippines.

Figure 22-2

Case Study: Using Refillable Containers

- Refilling and reusing containers uses fewer resources and less energy, produces less waste, saves money, and creates jobs.
  - In Denmark and Canada's Price Edward's Island there is a ban on all beverage containers that cannot be reused.
  - In Finland 95% of soft drink and alcoholic beverages are refillable (Germany 75%).

REUSE

Reducing resource waste: energy consumption for different types of 350-ml (12-oz) beverage containers.

Figure 22-7

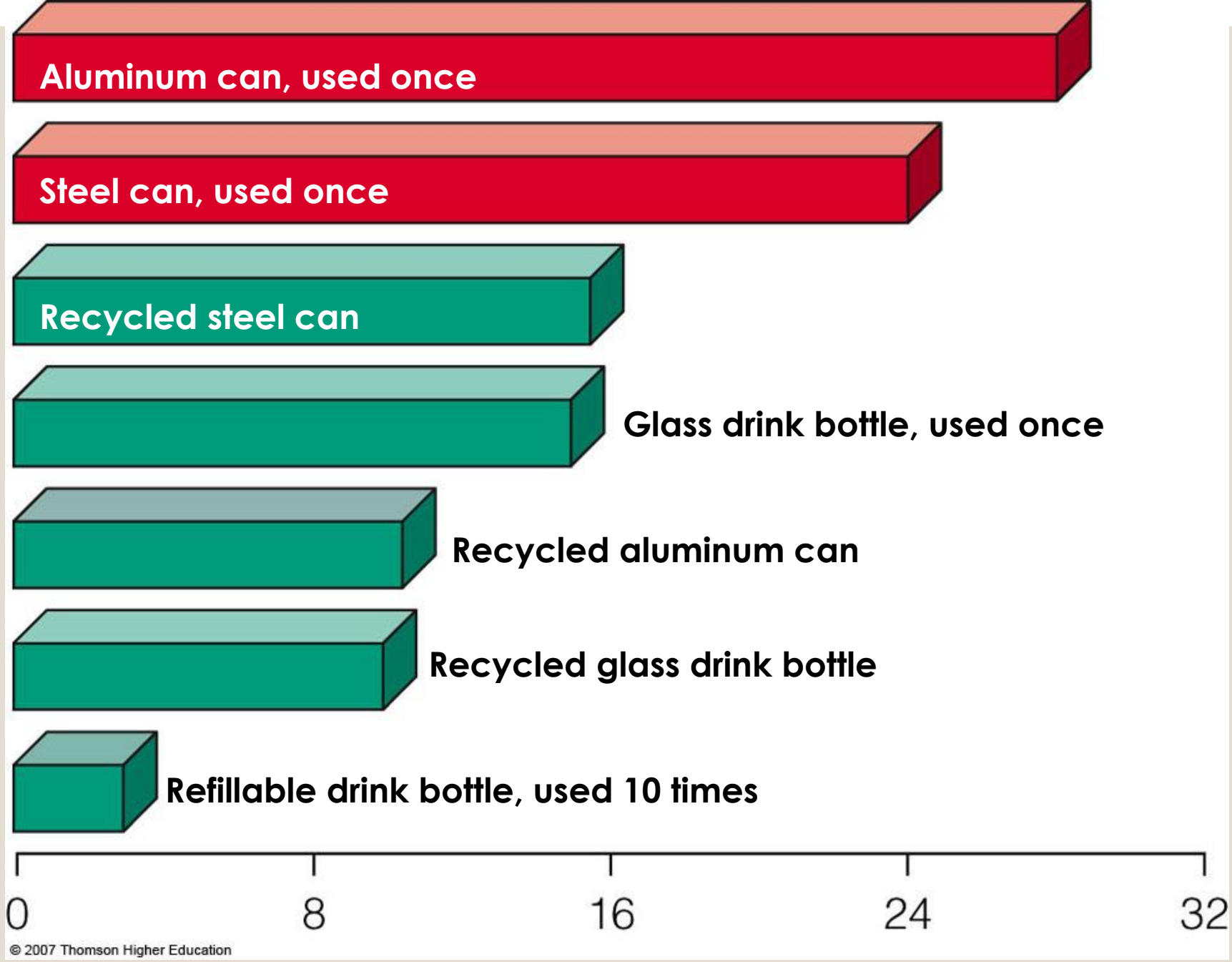

Aluminum can, used once
Steel can, used once
Recycled steel can
Glass drink bottle, used once
Recycled aluminum can
Recycled glass drink bottle
Refillable drink bottle, used 10 times
0
8
16
24
32
© 2007 Thomson Higher Education
Energy (thousands of kilocalories)

Fig. 22-7, p. 525

Solutions:
Other Ways to Reuse Things

- We can use reusable shopping bags, food containers, and shipping pallets, and borrow tools from tool libraries.
  - Many countries in Europe and Asia charge shoppers for plastic bags.

Recycling

- Recycling is the process by which materials destined to become MSW are collected and converted into raw materials that are then used to produce new objects
- 75% MSW recyclable if:
  - Mandatory
  - Easy to do
  - Incentives
  - Political and industrial support

State Recycling Rates

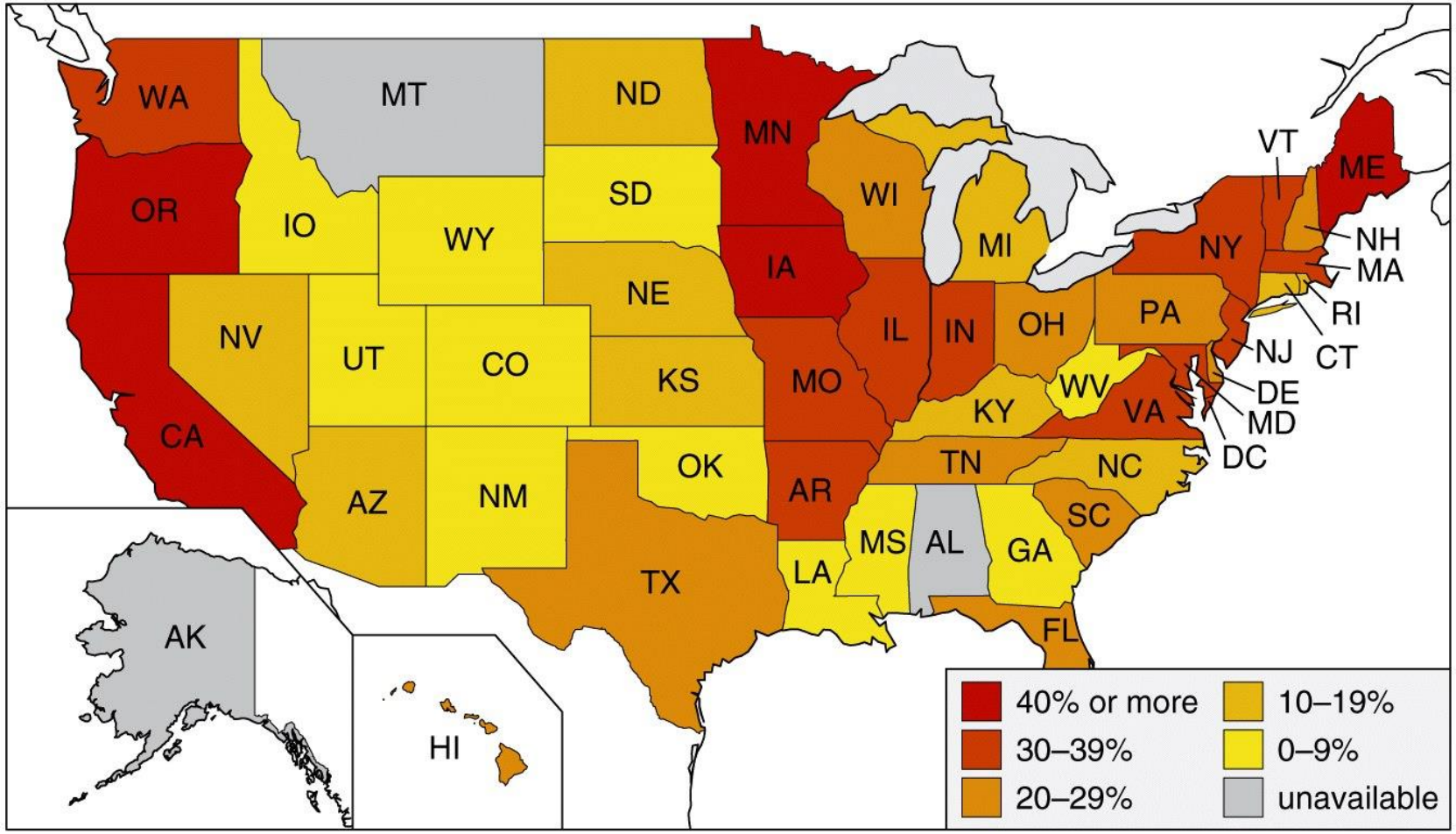


Figure 18-10 Environmental Science, 10/e

MSW Recycling in the United States

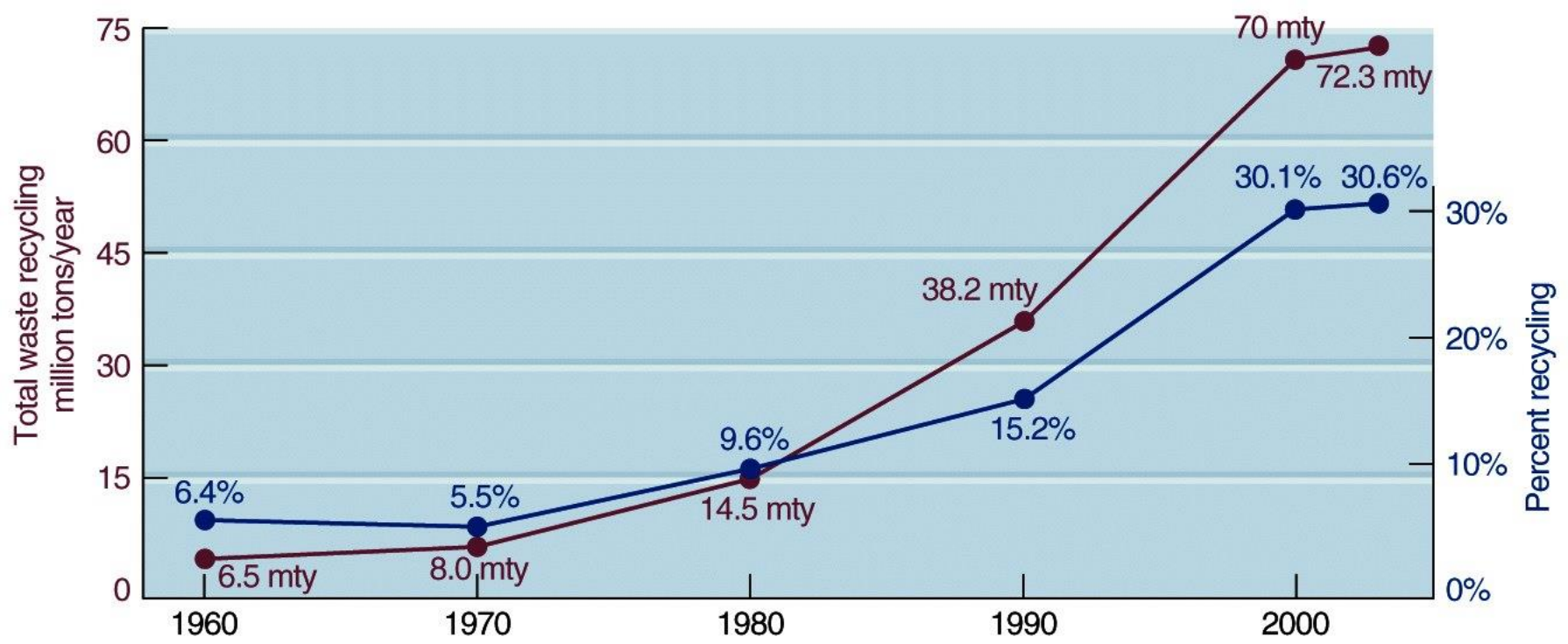


Figure 18-11 Environmental Science, 10/e

RECYCLING

- ***Primary (closed loop) recycling***: materials are turned into new products of the same type.
  - Aluminum cans
- ***Secondary recycling***: materials are converted into different products.
  - Used tires shredded and converted into rubberized road surface.
  - Newspapers transformed into cellulose insulation.
  - Plastic bottles turned into materials in a polar fleece jacket

RECYCLING

- There is a disagreement over whether to mix urban wastes and send them to centralized resource recovery plants or to sort recyclables for collection and sale to manufacturers as raw materials.
  - To promote separation of wastes, 4,000 communities in the U.S. have implemented ***pay-as-you-throw*** or ***fee-per-bag*** waste collection systems.

Pay-as-you-throw Trash Pickup

Figure 18-16 Environmental Science, 10/e

RECYCLING

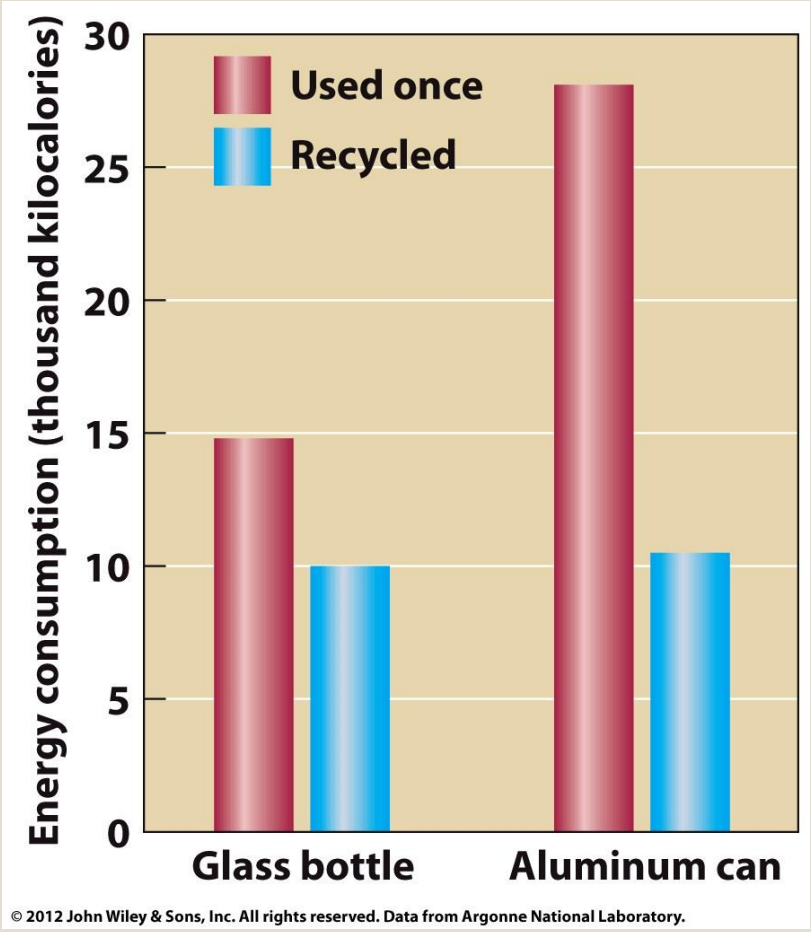
- Composting biodegradable organic waste mimics nature by recycling plant nutrients to the soil.
- Recycling paper has a number of environmental (reduction in pollution and deforestation, less energy expenditure) and economic benefits and is easy to do.

RECYCLING

- Recycling many plastics is chemically and economically difficult.
  - Many plastics are hard to isolate from other wastes.
  - Recovering individual plastic resins does not yield much material.
  - The cost of virgin plastic resins in low than recycled resins due to low fossil fuel costs.
  - There are new technologies that are making plastics biodegradable.

Recycling

- US recycles 38% of Municipal Solid Waste
- Recycling Paper
  - US recycles 62.1%
  - This has increased due to consumer demand for recycled paper products
- Recycling Glass
  - US recycles 25%
  - Costs producers less than new glass (right)



Recycling Glass

- U.S. recycles about 36% of its glass containers.
- It costs less to recycle glass than to make new glass.
- Mixed color glass "cullet" is used for glassphalt, a glass/asphalt mixture.

Recycling Aluminum

- This is the most recycled material in the U.S. because of $.
- Making a new can from an old one requires a fraction of the energy than to make a new can from raw materials.
- Approximately 2/3 of cans are recycled each year, saving 19 million barrels of oil annually.
  - 51% of aluminum was recycled in 2009
- Recycling Metals other than Aluminum
  - Lead, gold, iron, steel, silver and zinc
  - Metallic composition is often unknown
    - Makes recycling difficult

Recycling Paper

- U.S. currently recycles 40% of its paper and paperboard.
- Denmark, recycles about 97% of its paper.
- Many U.S. mills are not able to process waste paper.
- Many countries like Mexico, import a large amount of wastepaper from the U.S.
- We export about 19% of our recycled paper.

Recycling Materials

- Every ton of recycled paper saves:
  - 17 trees
  - 7000 gallons of water
  - 4100 kwatt-hrs of energy
  - 3 cubic yards of landfill space

Recycling

- Recycling Plastic
  - 14% of all plastic is recycled (2009)
    - Less expensive to make from raw materials
  - 28% of PET in water and soda bottles is recycled
  - Most plastic containers are made of many types of plastic that must be separated to be recycled

Courtesy National Association for PET Container Resources [NAPCOR]

Trade-Offs

Recycling

Advantages	Disadvantages
Reduces air and water pollution	Does not save landfill space in areas with ample land
Saves energy	May lose money for items such as glass and most plastic
Reduces mineral demand	Reduces profits from landfills and incinerators
Reduces greenhouse gas emissions	Source separation is inconvenient for some people
Reduces solid waste production and disposal	
Helps protect biodiversity	
Can save money for items such as paper, metals, and some plastics	
Important part of economy	

Fig. 22-9, p. 529

The Fate of Waste

- If not recycled it can be:
  - composted
  - sent to a landfill
  - incinerated

Compost

- Composting is a diversion pathway from a landfill that is almost as equally important as recycling
- Organic materials such as food and yard waste cause two problems in landfills-
  - Takes up space
  - Creates methane as they decompose anaerobically
- Composting is facilitating the decomposition of organic material in controlled conditions to produce organic-rich material that enhances soil structure and facility.

Compost

- If soil is properly aerated to allow for aerobic decomposition and contains the appropriate moisture level it will not produce methane = no foul smell.
- Benefits:
- Aerates the soil.
- Improves soil's ability to retain water and nutrients.
- Helps prevent erosion.
- Prevents nutrients from being dumped in landfills
- Can be sold commercially
- Decreases the amount of yard waste making its way to the landfill

Burying Solid Waste

- In the U.S. almost 1/3rd of our waste is recovered through reuse and recycling while more than half is discarded

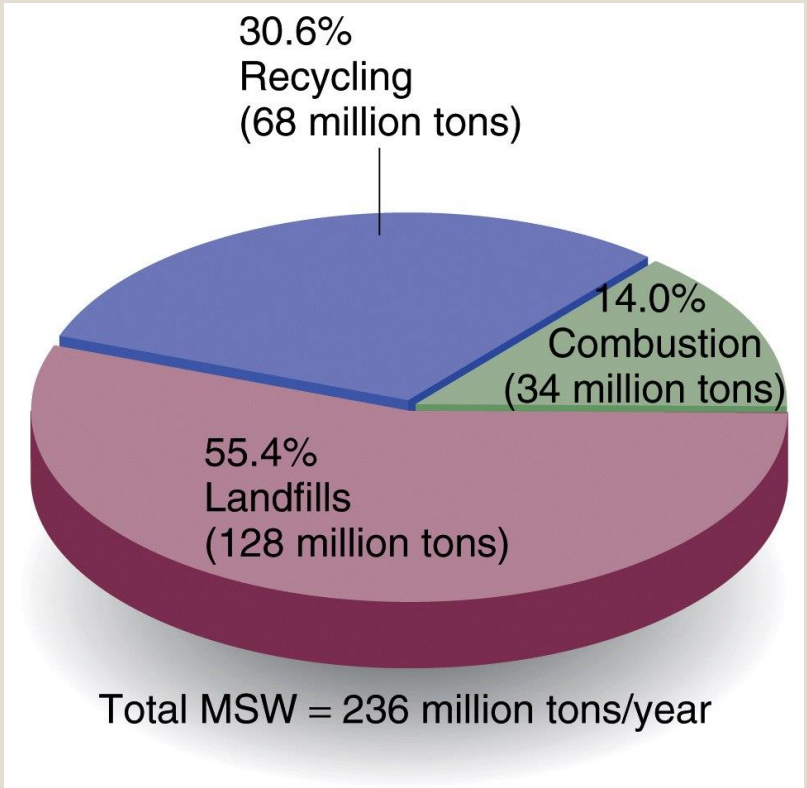


Figure 18-3 Environmental Science, 10/e

Burying Solid Waste

- Most of the world's MSW is buried in landfills that eventually are expected to leak toxic liquids into the soil and underlying aquifers.
  - ***Open dumps***: are fields or holes in the ground where garbage is deposited and sometimes covered with soil. Mostly used in developing countries.
  - ***Sanitary landfills***: solid wastes are spread out in thin layers, compacted and covered daily with a fresh layer of clay or plastic foam.

Landfills

- Sanitary landfill- engineered ground facilities designed to hold MSW with as little contamination of the surrounding environment as possible
  - Most common method of disposal
  - Constructed with clay or plastic lining the bottom.
    - Clay can impede water flow
  - A system of pipes below the landfill collect leachate
  - When the landfill reaches capacity it is covered with a soil and clay cap

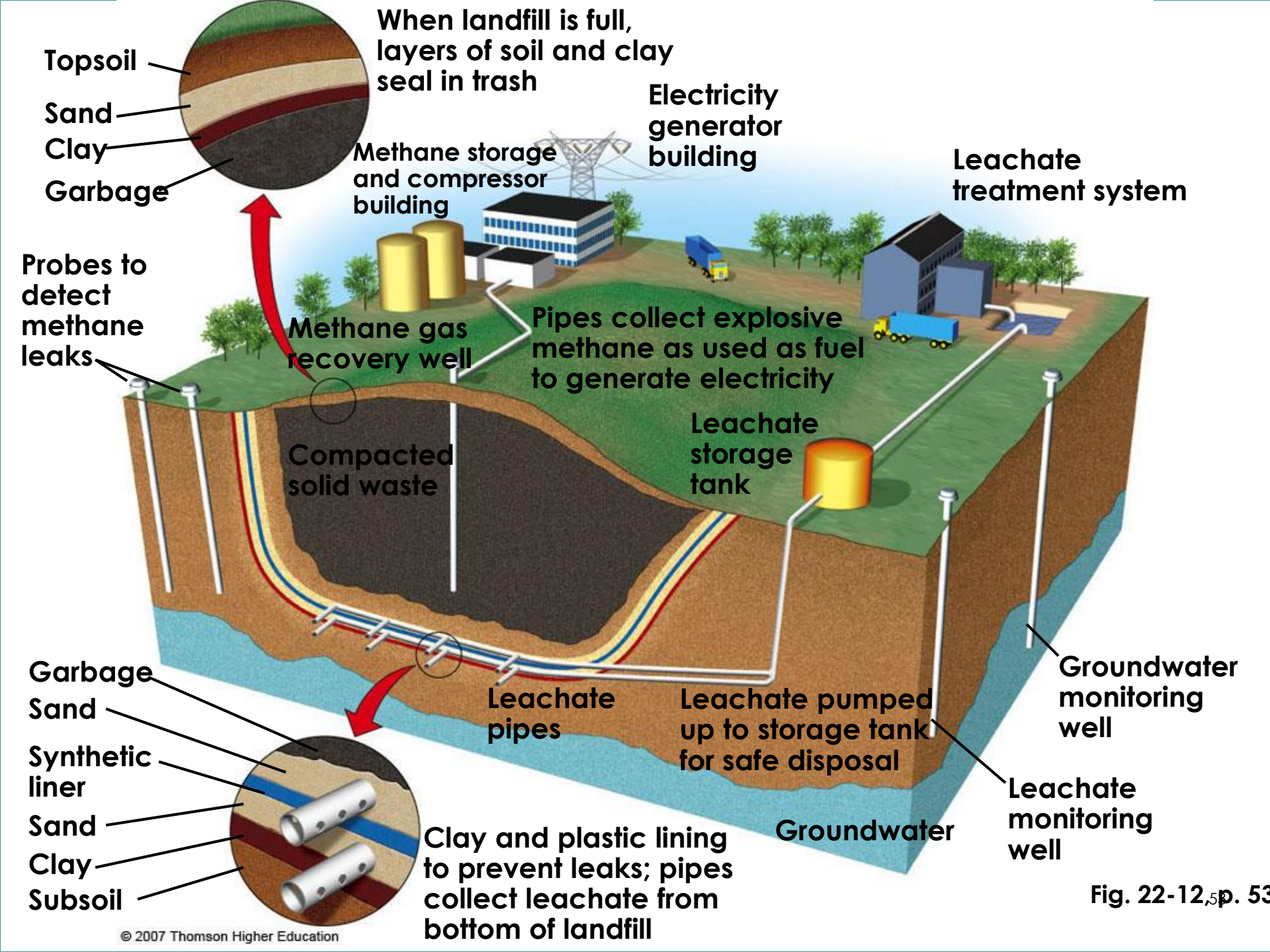

When landfill is full, layers of soil and clay seal in trash
Topsoil
Sand
Clay
Garbage
Electricity generator building
Methane storage and compressor building
Leachate treatment system
Probes to detect methane leaks
Methane gas recovery well
Pipes collect explosive methane as used as fuel to generate electricity
Compacted solid waste
Leachate storage tank
Garbage
Sand
Synthetic liner
Sand
Clay
Subsoil
Leachate pipes
Leachate pumped up to storage tank for safe disposal
Groundwater monitoring well
Leachate monitoring well
Groundwater
Clay and plastic lining to prevent leaks; pipes collect leachate from bottom of landfill
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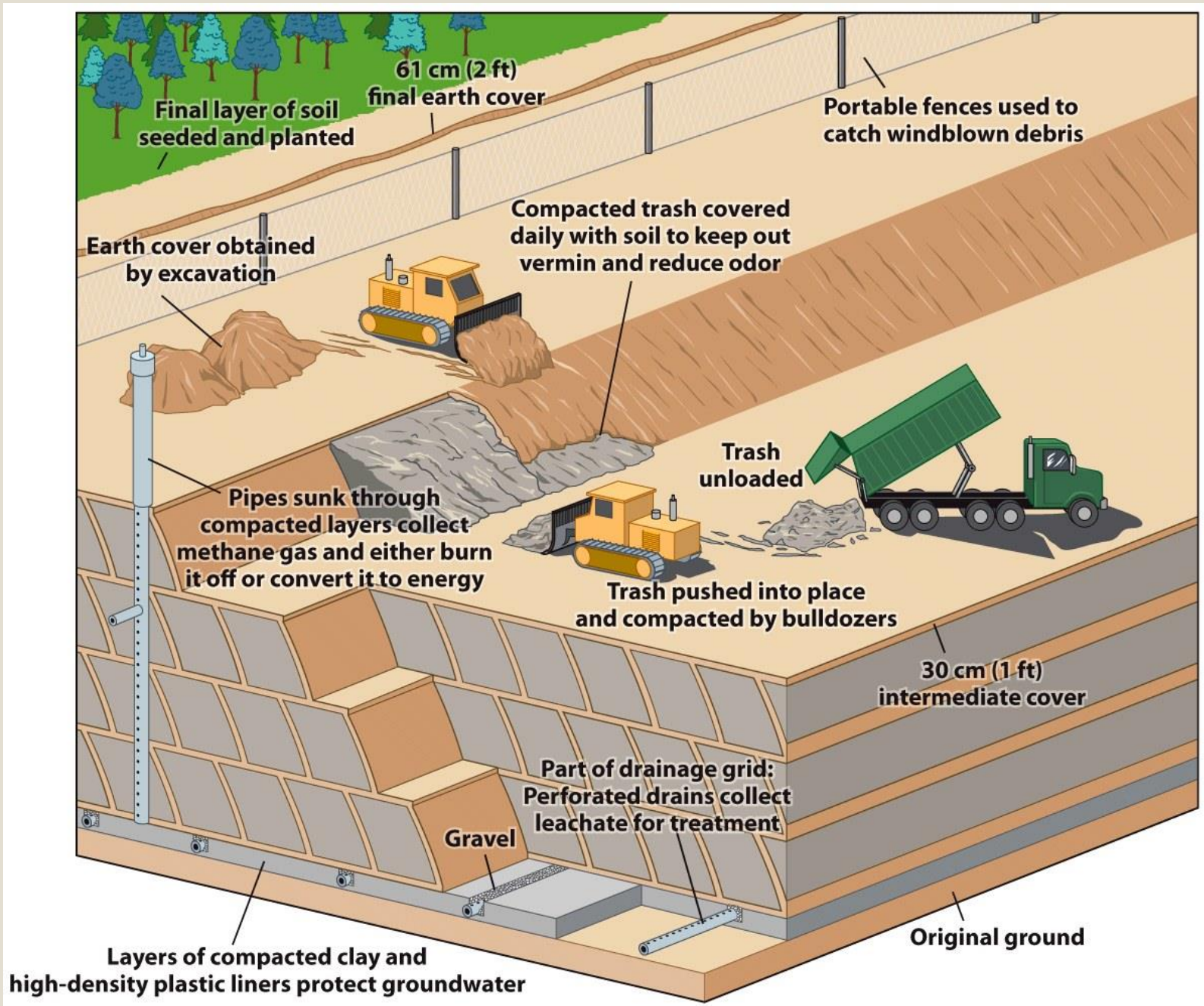
Fig. 22-12, p. 53

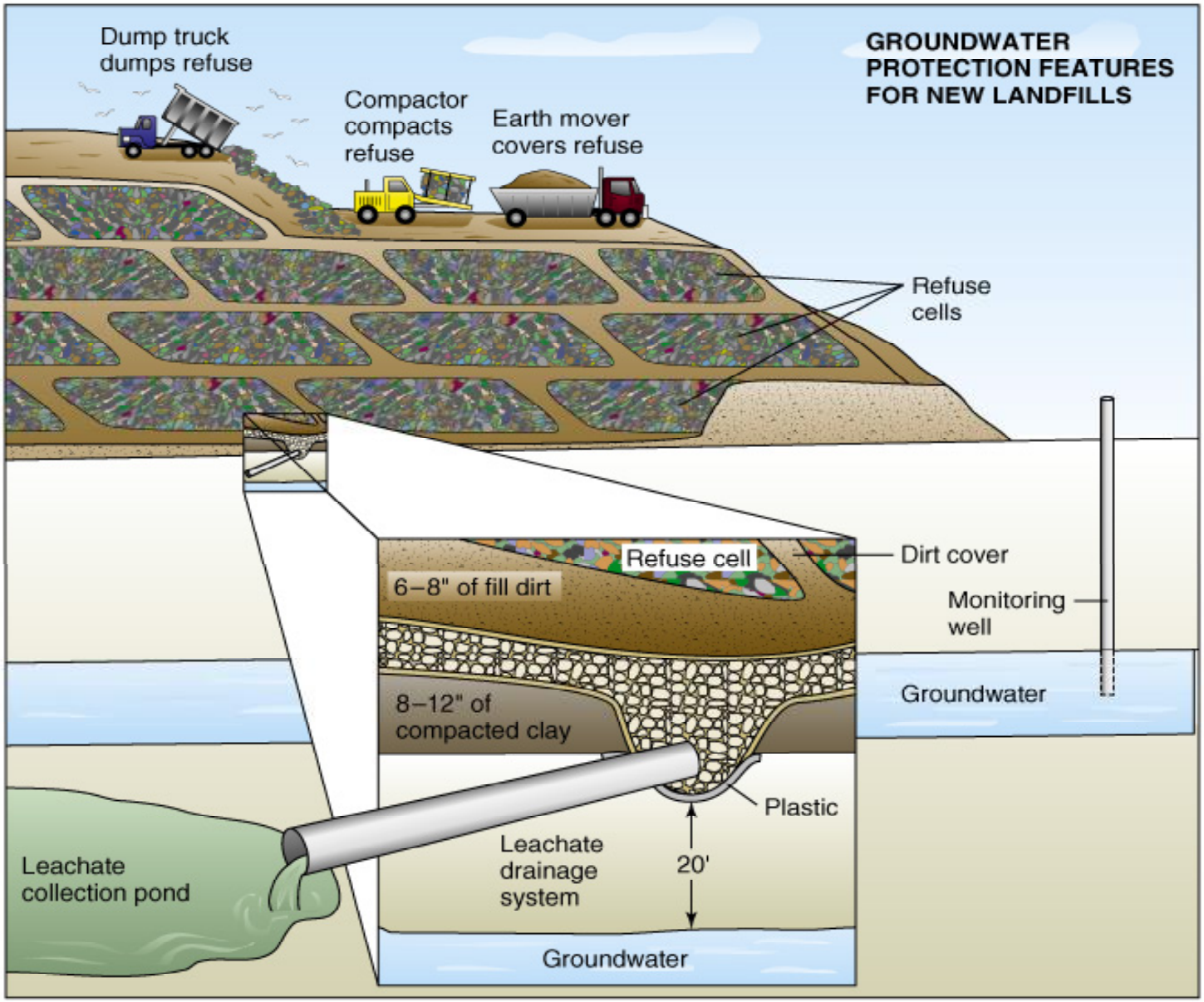


Landfills

- Problems
  - Methane gas production by microorganisms
  - Contamination of surface water & ground water by leachate
  - Not a long-term remedy
  - Few new facilities being opened
  - Closing a full landfill is very expensive
  - Incomplete decomposition

Improving Landfills

- Located above water table and away from airports
- Contoured floor for leachate-collection system
- Covered with earthen material
- Ground-water monitoring wells


GROUNDWATER
PROTECTION FEATURES
FOR NEW LANDFILLS
Dump truck
dumps refuse
Compactor
compacts
refuse
Earth mover
covers refuse
Refuse
cells
Refuse cell
Dirt cover
6–8" of fill dirt
Monitoring
well
Groundwater
8–12" of
compacted clay
Plastic
Leachate
collection pond
Leachate
drainage
system
20'
Groundwater

Trade-Offs

Sanitary Landfills

Fig. 22-13, p. 533

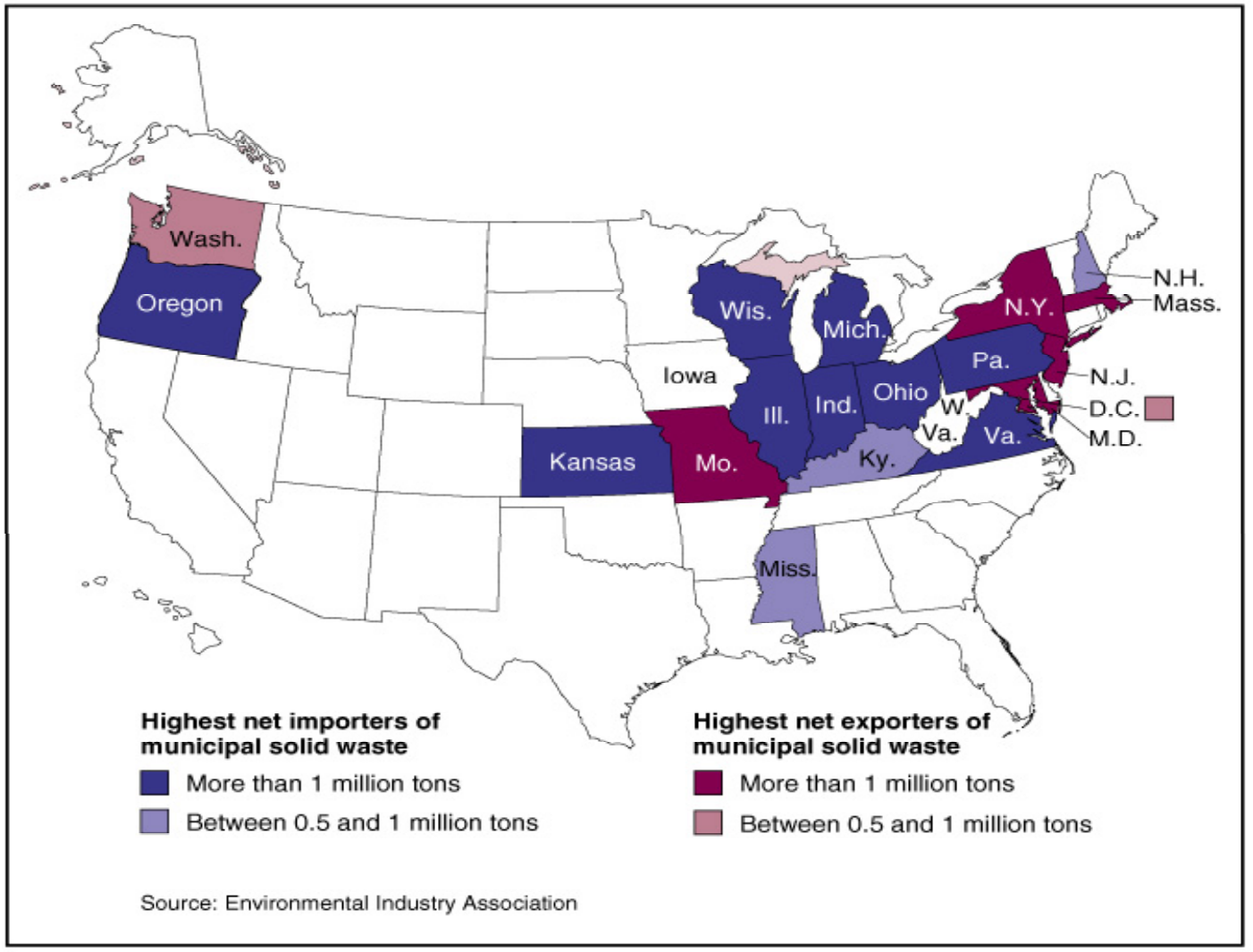
Advantages	Disadvantages
No open burning	Noise and traffic
Little odor	Dust
Low groundwater pollution if sited properly	Air pollution from toxic gases and volatile organic compounds
Can be built quickly	Releases greenhouse gases (methane and CO_2) unless they are collected
Low operating costs	Groundwater contamination
Can handle large amounts of waste	Slow decomposition of wastes
Filled land can be used for other purposes	Discourages recycling, reuse, and waste reduction
No shortage of landfill space in many areas	Eventually leaks and can contaminate groundwater

Landfills Siting: Public Reactions

- The siting, or designation of a landfill location is controversial
- NIMBY (not in my backyard)
- NIMTOO (not in my term of office)

http://www.zerowasteamerica.org/Pictures.htm

Interstate Transfer of MSW



Trash to Treasure

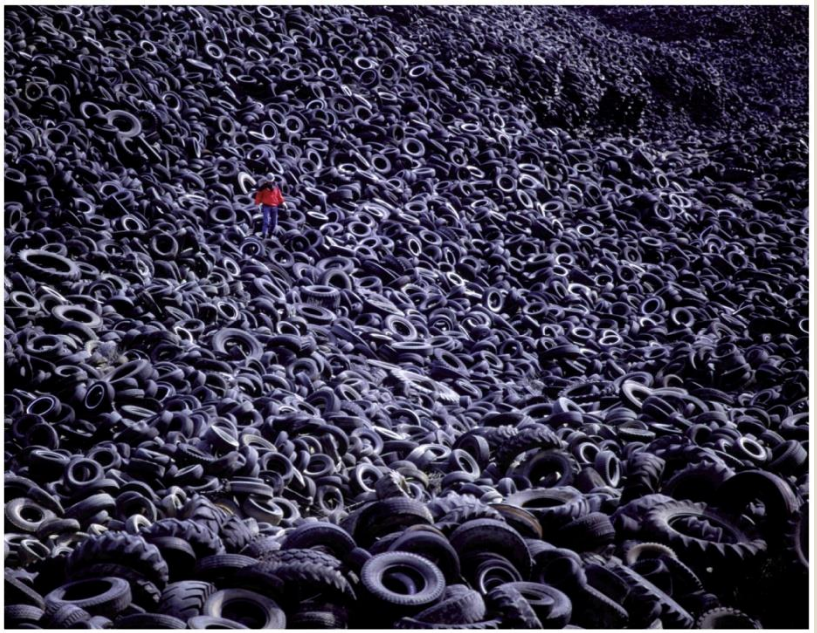
- Highest (more than 1 million tons) net importers of MSW
  - Pennsylvania
  - Virginia
  - Michigan
  - Ohio

- Highest (more than 1 million tons) net exporters of MSW
  - New York
  - New Jersey
  - Ontario, Canada
  - Missouri

Sanitary Landfill

- Special Problem: Plastic
  - Much of plastic is from packaging
  - Chemically stable and do not readily break down and decompose

- Special Problem: Tires
  - Made from materials that cannot be recycled
  - Can be incinerated or shredded



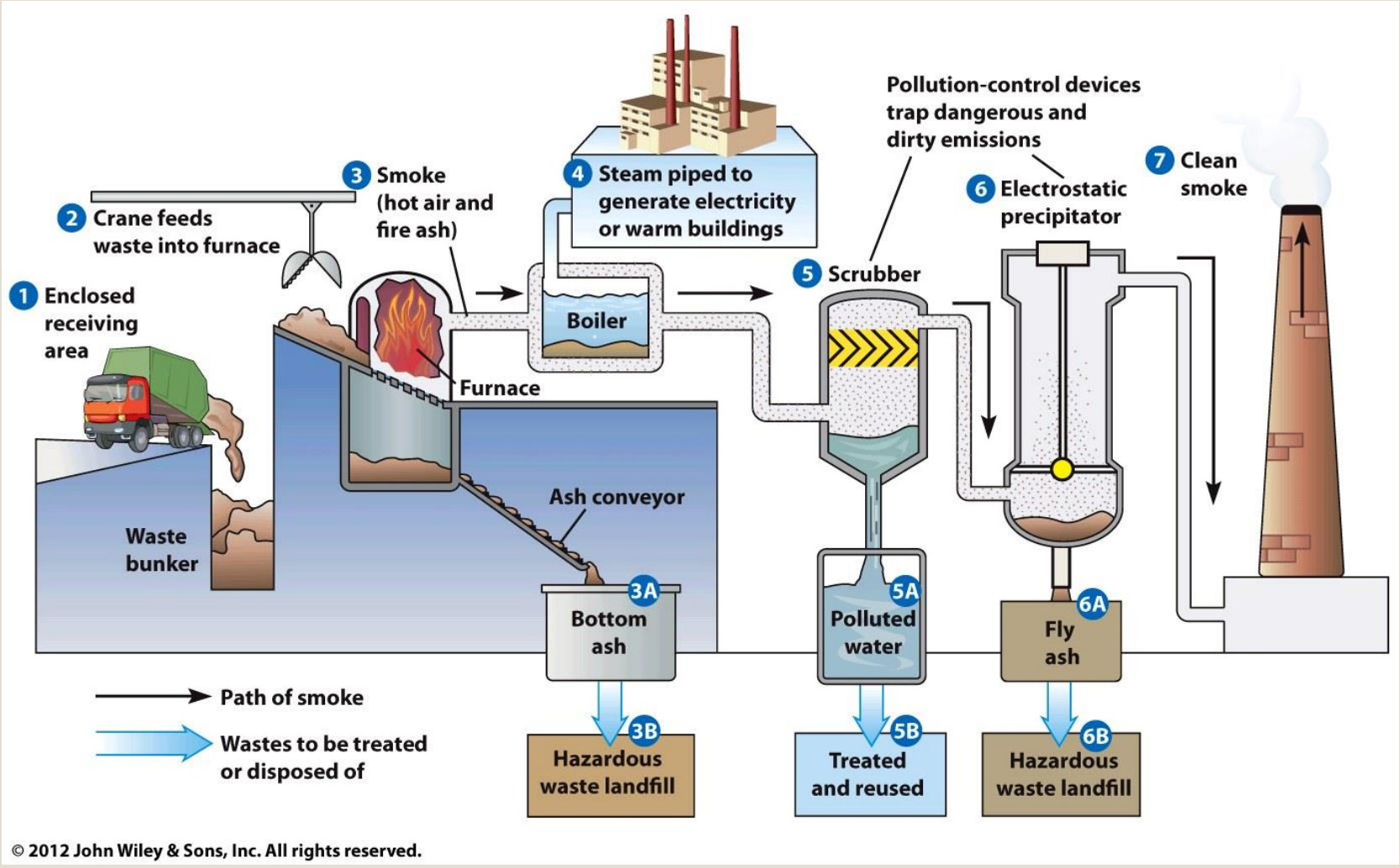
Jose Azel/Aurora Photos, Inc.

Case Study: What Should We Do with Used Tires?

- We face a dilemma in deciding what to so with hundreds of millions of discarded tires.
- More than 800 million used tires have accumulated in large dumps or vacant lots
- ~273 million more tires are discarded each year
- Health hazard- collect stagnant water
- Can burn for weeks in highly polluting fires that are almost impossible to put out

Figure 22-14

Incineration



Incineration

- Globally, MSW is burned in over 1,000 large ***waste-to-energy incinerators***, which boil water to make steam for heating water, or space, or for production of electricity.
  - Japan and a few European countries incinerate most of their MSW.

Incineration

- MSW is dumped, or "tipped" onto a platform where metals are identified and removed
- A moving grate transfers waste to a furnace
- Heat is released as combustion rapidly converts much of the waste into carbon dioxide and water which is released into the atmosphere

Incineration

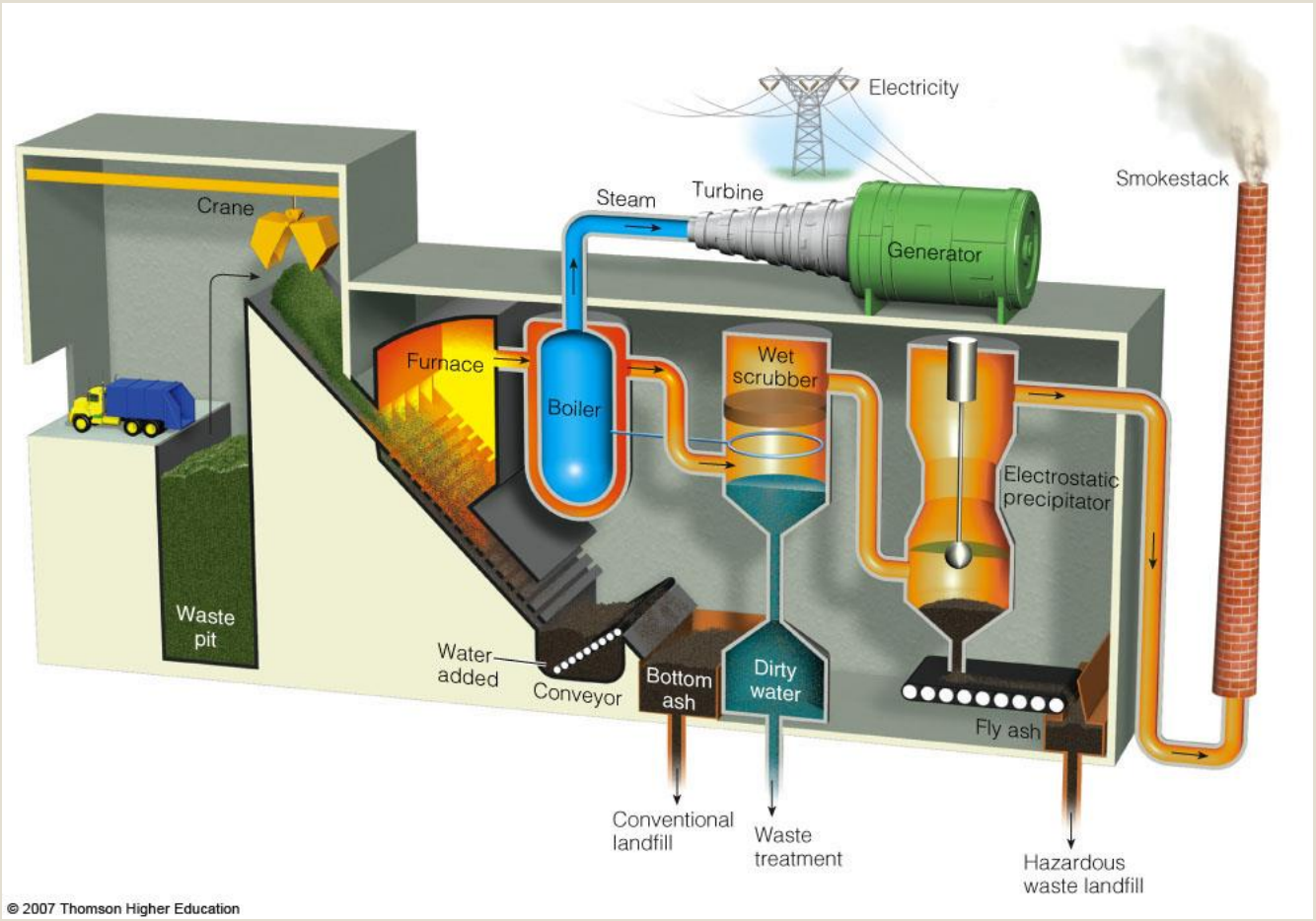
- Particulates are the end product of combustion
  - More commonly known as ash
  - Ash- the residual nonorganic material that does not combust during incineration.
  - Bottom ash- collected underneath the furnace
  - Fly ash- residue collected beyond the furnace
    - Typically fills 1/4th the volume of the precombustion material

Avoiding Pollution

- The possible production of hazardous air pollutants is the main reason people oppose incineration.
  - Carbon monoxide
  - Particulates
  - Heavy metals
- Control devices are used-
  - Lime scrubbers
  - Electrostatic precipitators

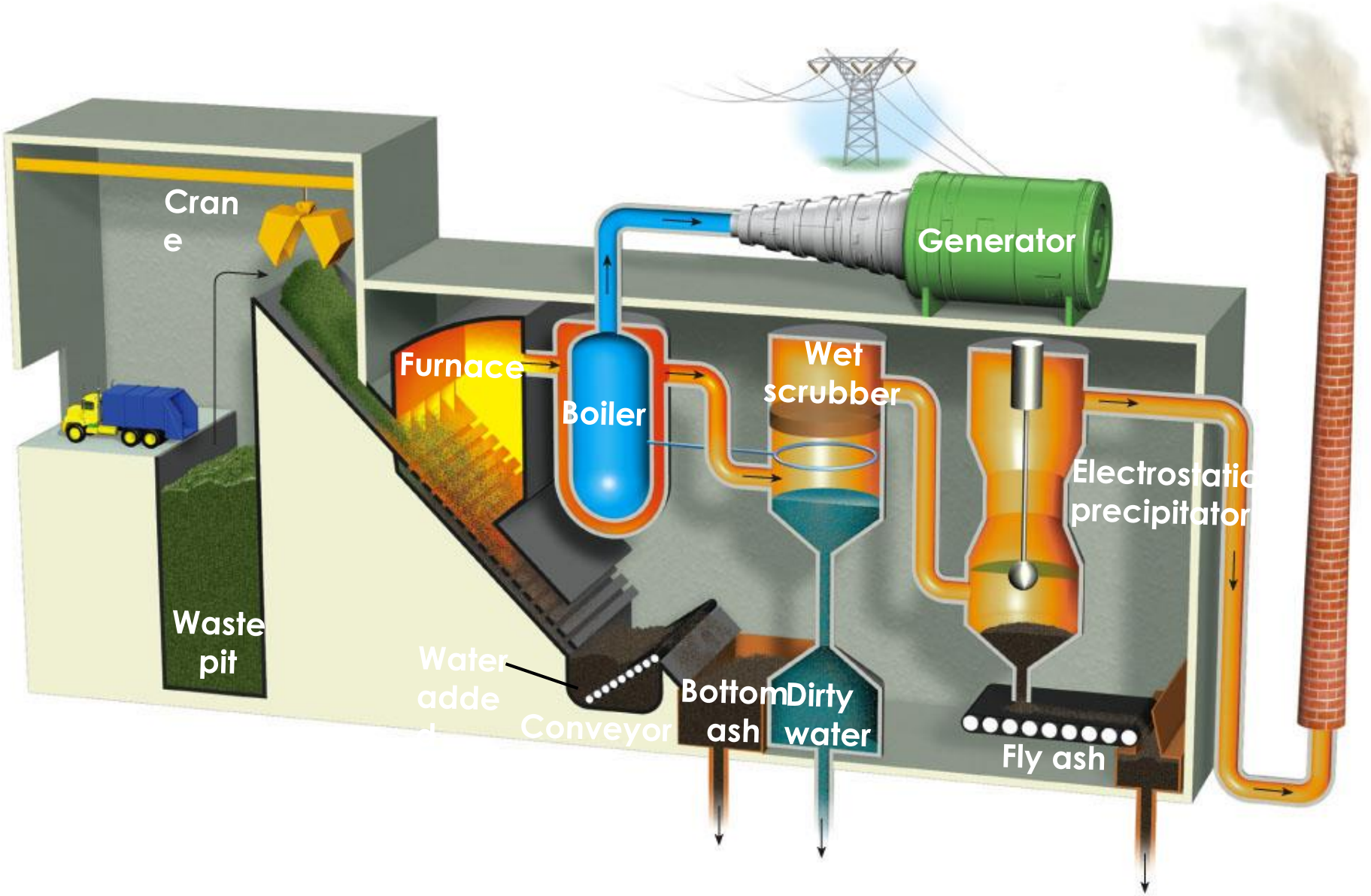
- Lime scrubbers
  - Towers which a chemical spray neutralizes acidic gases
- Electrostatic precipitators
  - Give ash a positive electrical charge so that it adheres to negatively charged plates rather than going out the chimney

Burning Solid Waste



- Waste-to-energy incinerator with pollution controls that burns mixed solid waste.

Figure 22-10



Trade-Offs

Incineration

Advantages	Disadvantages
Reduces trash volume	Expensive to build
Less need for landfills	Costs more than short-distance hauling to landfills
Low water pollution	Difficult to site because of citizen opposition
Concentrates hazardous substances into ash for burial or use as landfill cover	Some air pollution
Sale of energy reduces cost	Older or poorly managed facilities can release large amounts of air pollution
Modern controls reduce air pollution	Output approach that encourages waste production
Some facilities recover and sell metals	Can compete with recycling for burnable materials such as newspaper

Fig. 22-11, p. 531

Combustion Advantages

- Reduction trash weight (70%) and volume (90%) - increases life of landfill
- Control of toxic or hazardous substances
  - Fly ash and Bottom ash are tested for toxicity and spent to specific/special landfills
- Same trash collection procedures
- Two-thirds are WTE facilities in compliance with Clean Air Act regs.

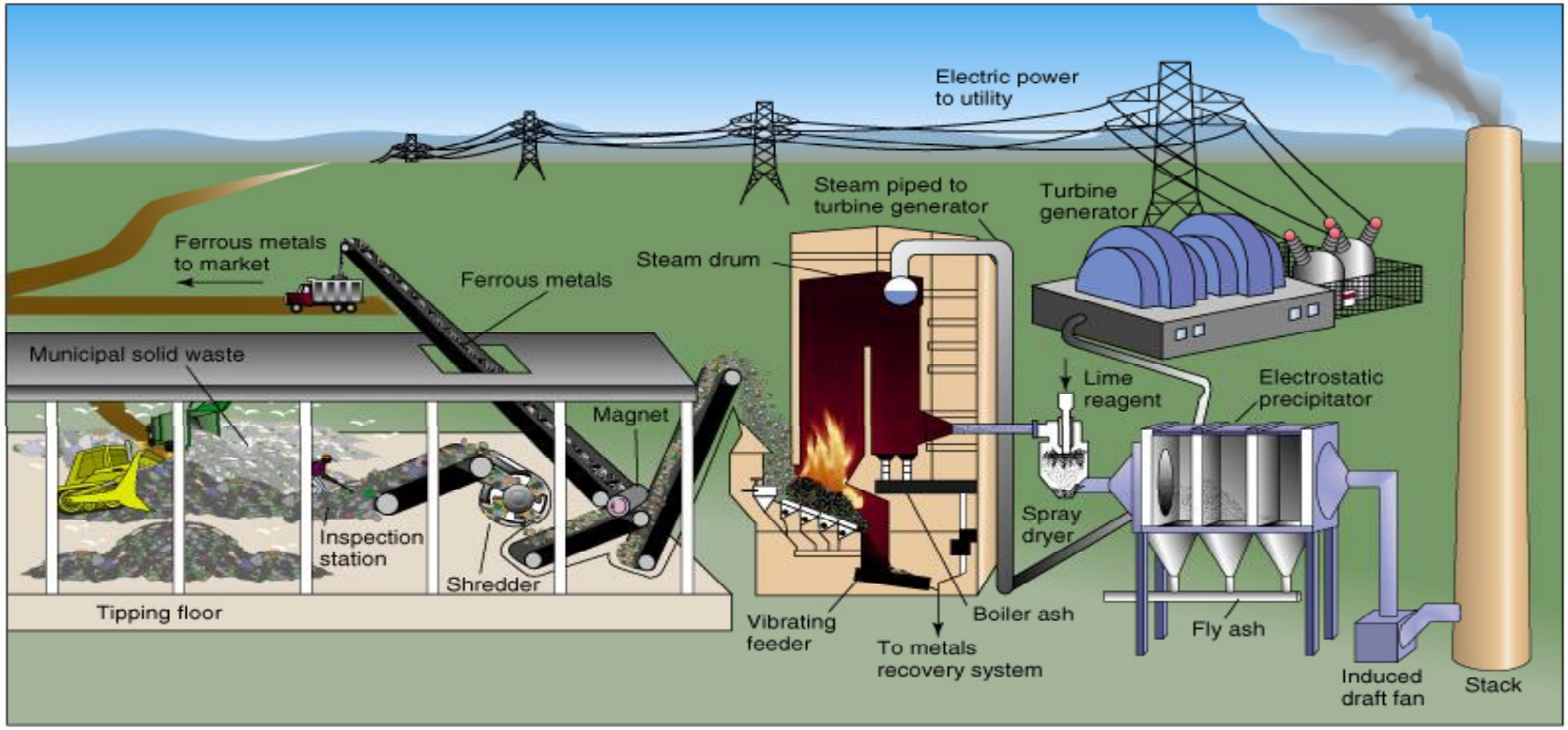
Combustion Advantages

- Produce 2,700 megawatts of electricity meeting power needs of 2.3 million homes
- Resource recovery

Combustion Drawbacks

- Cost of construction
- Uninterrupted MSW stream flow
- Siting – offensive odors
- Competition with recycling efforts
- Production of hazardous air pollutants
  - Carbon monoxide, particulates, heavy metals
  - Reduced by
    - Lime Scrubbers
    - Electrostatic Precipitators
- Byproduct - Bottom ash and Fly ash
  - Must be disposed of in hazardous waste landfills

Waste-to-Energy Operating Facility



HAZARDOUS WASTE

- ***Hazardous waste***: is any discarded solid or liquid material that is toxic, ignitable, corrosive, or reactive enough to explode or release toxic fumes.
  - The two largest classes of hazardous wastes are organic compounds (e.g. pesticides, PCBs, dioxins) and toxic heavy metals (e.g. lead, mercury, arsenic).

Hazardous Waste

Table 23.1 Examples of Hazardous Waste

Hazardous Material	*Some Possible Sources*
Acids	Ash from power plants and incinerators; petroleum products
CFCs (chlorofluorocarbons)	Coolant in air conditioners and refrigerators
Cyanide	Metal refining; fumigants in ships, railway cars, and warehouses
Dioxins	Emissions from incinerators and pulp and paper plants
Explosives	Old military installations
Heavy metals	Paints, pigments, batteries, ash from incinerators, sewage sludge with industrial waste, improper disposal in landfills
Arsenic	Industrial processes, pesticides, additives to glass, paints
Cadmium	Rechargeable batteries, incineration, paints, plastics
Lead	Lead-acid storage batteries, stains and paints, TV picture tubes and electronics discarded in landfills
Mercury	Coal-burning power plants; paints, household cleaners (disinfectants), industrial processes, medicines, seed fungicides
Infectious waste	Hospitals, research labs
Nerve gas	Old military installations
Organic solvents	Industrial processes; household cleaners, leather, plastics, pet maintenance (soaps), adhesives, cosmetics
PCBs (polychlorinated biphenyls)	Older appliances (built before 1980); electrical transformers and capacitors
Pesticides	Household products
Radioactive waste	Nuclear power plants, hospitals, and weapons production/dismantling facilities

Hazardous Waste

- Industry, mining, households, small businesses, agriculture, utilities and building demolition all create hazardous wastes
  - Industry produces the largest but in developed countries waste generation and disposal is highly regulated
  - Households are the largest source of unregulated waste
    - Paints, batteries, oils, solvents, cleaning agents and pesticides
    - Average household has ~100lbs around their house

Hazardous Waste

- Dioxin
  - Formed as byproduct of combustion of chlorine compounds
  - Bioaccumulate and biomagnify through foodweb
  - Cause cancer, effect reproductive, immune and nervous system
- PCBs
  - Used as cooling fluid, fire retardant, lubricator
    - Disposed of in open dumps, sewers and fields in 1970s - issue in groundwater today
  - Endocrine disrupter

Hazardous Waste

- Regulations of hazardous waste-
  - In 1980 Congress Passed CERCLA (Comprehensive Environmental Response Compensation and Liability Act
  - Federal program to clean up U.S. sites polluted with hazardous waste from past activities
  - The EPA administers this cleanup program called the Superfund
  - EPA later was charged with cleaning up Brownfields- lands whose reuse or development are complicated by the presence of hazardous materials

Superfund Program

- Pesticides dumps
- Piles of mining wastes
- Must be cleaned up
  - 2011 - over 11,000 sites on list

- Cleaning up existing hazardous waste:
  - 400,000 waste sites
  - Leaking chemical storage tanks and drums (below)

Courtesy USDA

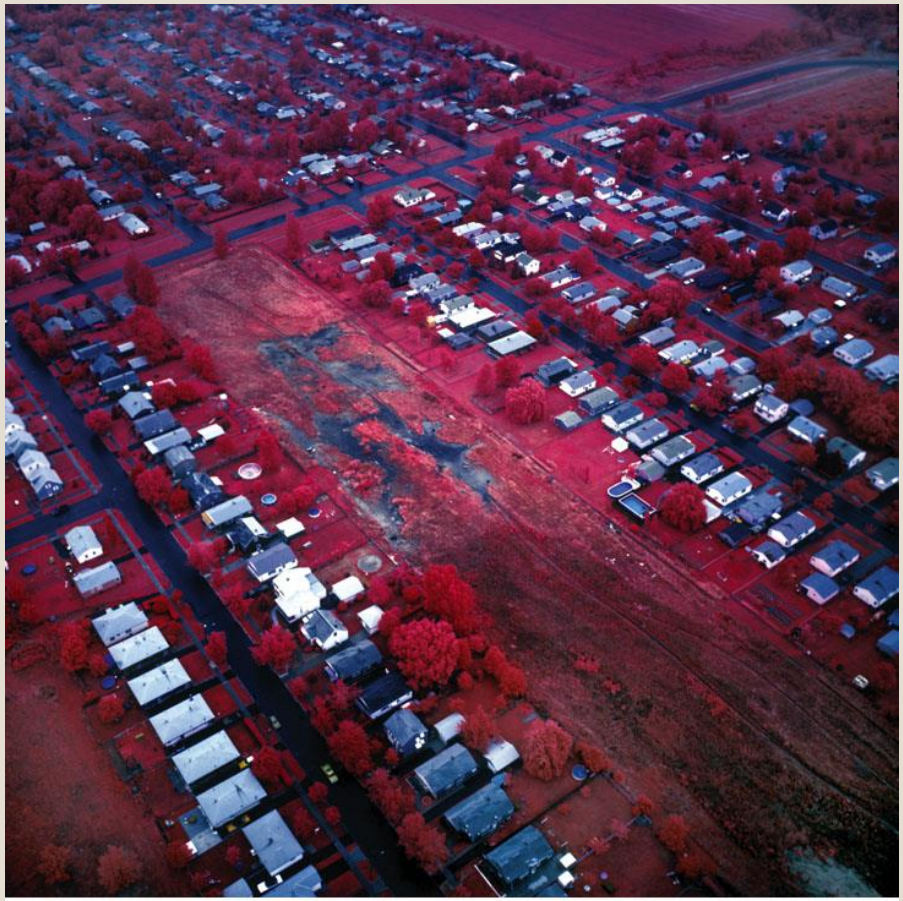
Core Case Study: Love Canal — There Is No "Away"

- Between 1842-1953, Hooker Chemical sealed multiple chemical wastes into steel drums and dumped them into an old canal excavation (Love Canal).
- In 1953, the canal was filled and sold to Niagara Falls school board for $1.
- The company inserted a disclaimer denying liability for the wastes.

Core Case Study: Love Canal — There Is No "Away"

- In 1957, Hooker Chemical warned the school not to disturb the site because of the toxic waste.
  - In 1959 an elementary school, playing fields and homes were built disrupting the clay cap covering the wastes.
  - In 1976, residents complained of chemical smells and chemical burns from the site.

Core Case Study: Love Canal — There Is No "Away"



- President Jimmy Carter declared Love Canal a federal disaster area.
  - The area was abandoned in 1980 (left).

Figure 22-1

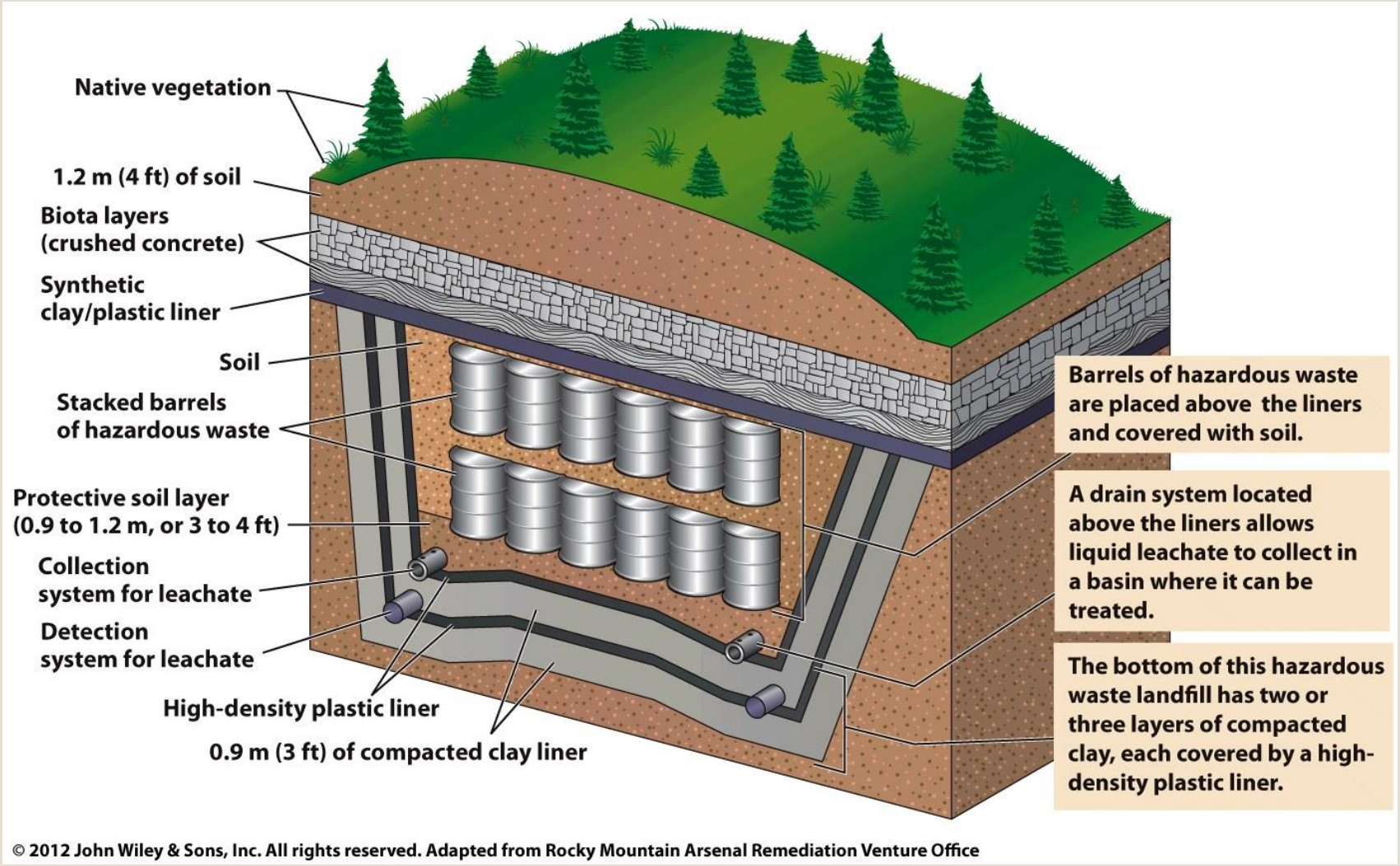
Core Case Study: Love Canal — There Is No "Away"

- It still is a controversy as to how much the chemicals at Love Canal injured or caused disease to the residents.
- Love Canal sparked creation of the Superfund law, which forced polluters to pay for cleaning up abandoned toxic waste dumps.

Hazardous Waste

- There are 3 primary means to dispose:
  - Landfills
  - Surface impoundments
  - Infection wells
- They don't make them less hazardous but instead just isolate them from people, wildlife and ecosystems

Hazardous Waste Landfill



Secure Hazardous Waste Landfill

- In the U.S. there are only 23 commercial hazardous waste landfills.

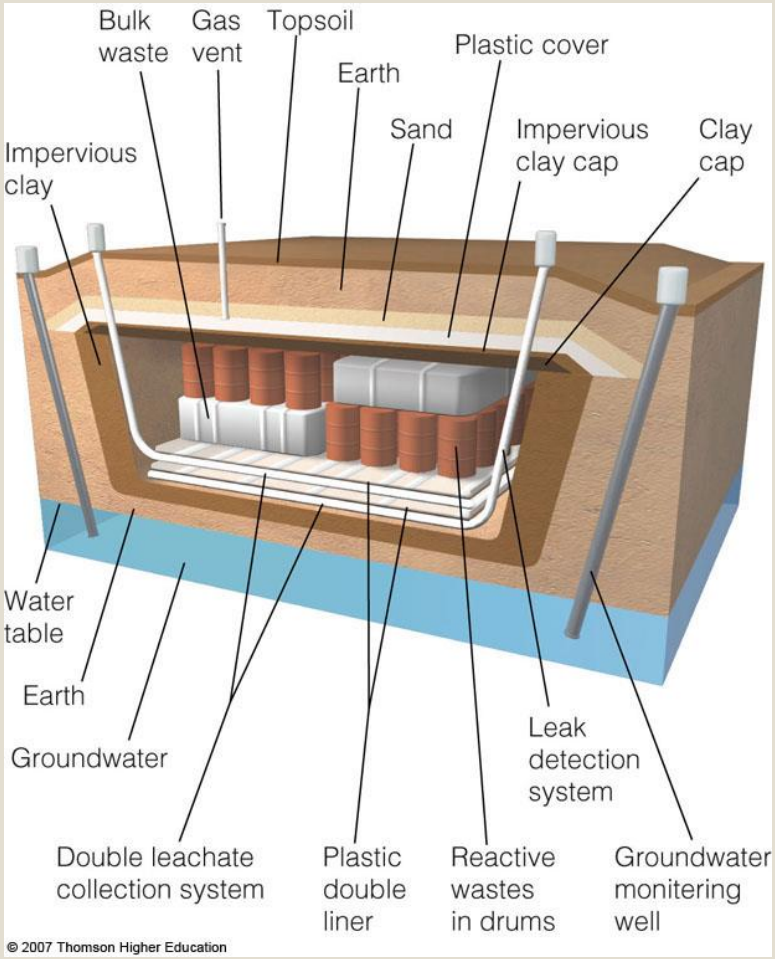


Figure 22-22

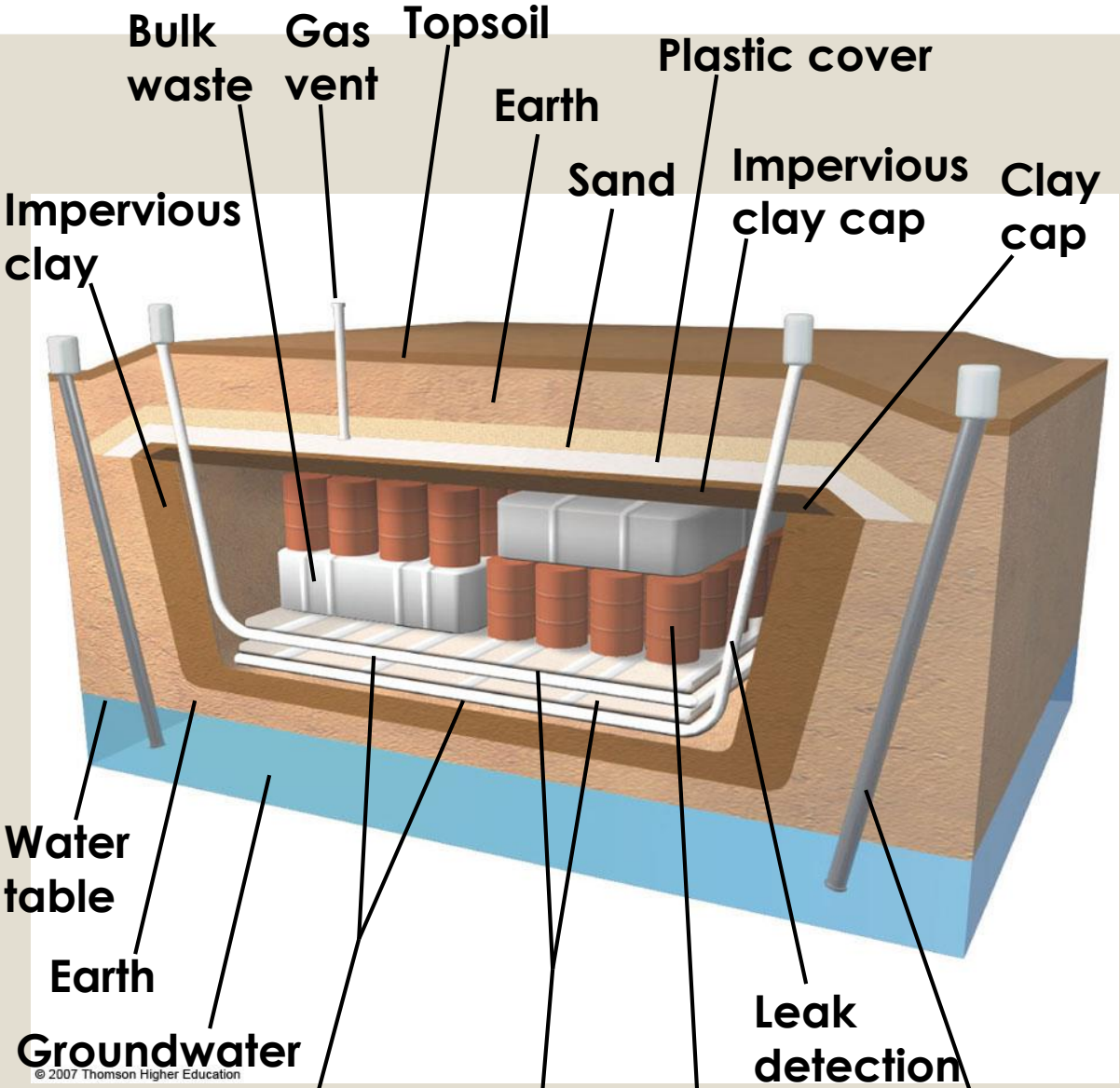


Fig. 22-22, p. 540

Hazardous Waste

- Surface impoundments
  - Shallow depressions lined with plastic and impervious material, such as clay
  - Liquid hazardous waste is stored in such ponds
  - Water evaporates from the liquid leaving residue of solid hazardous waste t be removed once dry
  - Not ideal disposal- underlying layer can crack and leak, some material may evaporate are blow into surrounding areas, rainstorms can cause waste to overflow
  - Used essentially for temporary storage

Trade-Offs

Surface Impoundments

Advantages	Disadvantages
Low construction costs	Groundwater contamination from leaking liners (or no lining)
Low operating costs	Air pollution from volatile organic compounds
Can be built quickly	Overflow from flooding
Wastes can be retrieved if necessary	Disruption and leakage from earthquakes
Can store wastes indefinitely with secure double liners	Promotes waste production

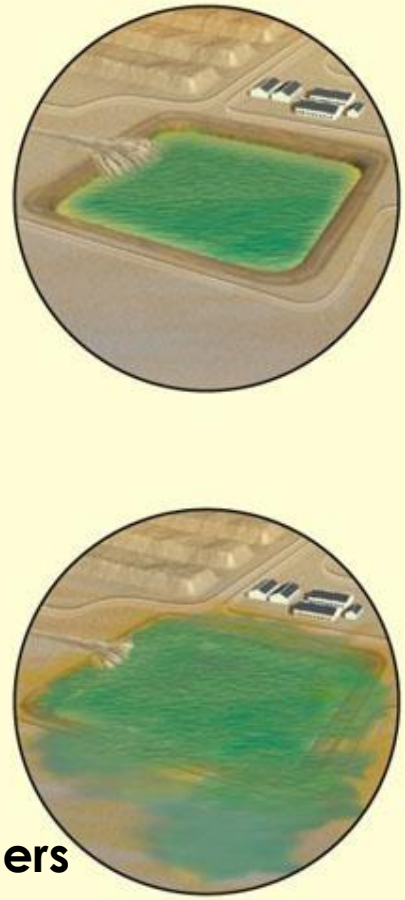


Fig. 22-21, p. 539

Hazardous Waste

- Deep-well injections
  - A well is drilled deep beneath the water table into porous rock and wastes are injected into it
  - Long term disposal
  - Isolated from ground water and human contact
  - Wells can corrode and leak wastes into the soil and contaminate aquifers
  - ~9 billion gallons of hazardous waste is placed in deep well injections each year

Trade-Offs

Deep Underground Wells

Advantages	Disadvantages
Safe method if sites are chosen carefully	Leaks or spills at surface
Wastes can be retrieved if problems develop	Leaks from corrosion of well casing
Easy to do	Existing fractures or earthquakes can allow wastes to escape into groundwater
Low cost	Encourages waste production

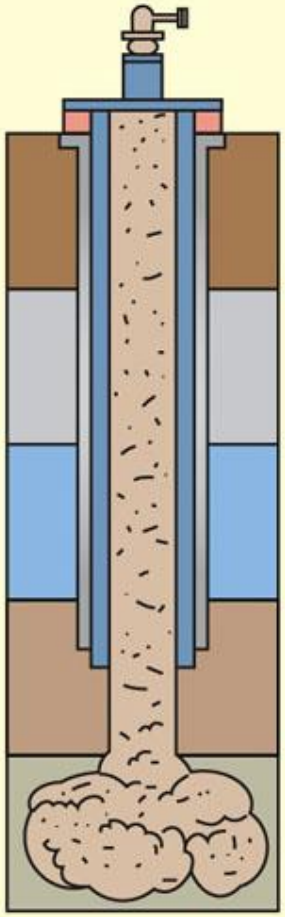


Fig. 22-20, p. 539

Conversion to Less Hazardous Substances

We can convert hazardous substances into less harmful materials

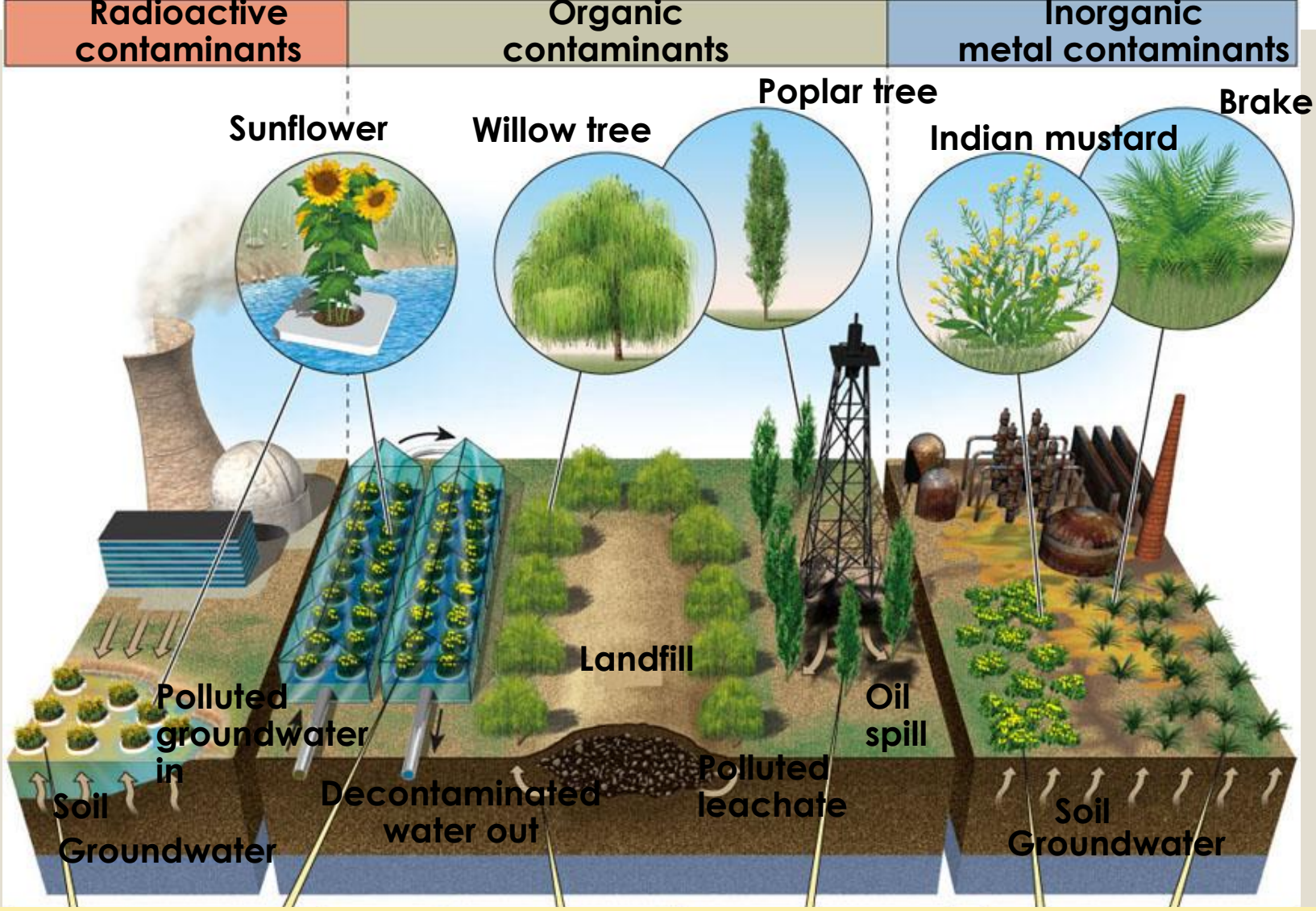
- ***Physical Methods***: using charcoal or resins to separate out harmful chemicals.
- ***Chemical Methods***: using chemical reactions that can convert hazardous chemicals to less harmful or harmless chemicals.

Management of Hazardous Waste

- Biological Treatment of Hazardous Chemicals
  - Bioremediation - use of bacteria and other microorganisms to break down hazardous waste into relatively harmless products
    - 1000 species of bacteria and fungi
    - Time consuming
    - Inexpensive
  - Phytoremediation- use of plants to absorb and accumulate hazardous materials in the soil
    - Ex: Indian mustard removes heavy metals

Examples of Phytoremediation

Phytoextraction	Phytostabilization	Phytodegradation
		
Hybrid poplar	***Indian mustard***	***Willow***
Plant roots absorb contaminant from soil and accumulate it in root and shoot tissues; later, plants are harvested and disposed of in a hazardous waste landfill.	**Plant roots immobilize contaminant in soil by adsorption to roots or precipitation in root zone of soil, keeping contaminant from reaching nearby groundwater.**	**Plant roots absorb contaminant and break it down into more benign chemicals.**



Rhizofiltration
Roots of plants such as sunflowers with dangling roots on ponds or in green-houses can absorb pollutants such as radioactive strontium-90 and cesium-137 and various organic chemicals.

Phytostabilization
Plants such as willow trees and poplars can absorb chemicals and keep them from reaching groundwater or nearby surface water.

Phytodegradation
Plants such as poplars can absorb toxic organic chemicals and break them down into less harmful compounds which they store or release slowly into the air.

Phytoextraction
Roots of plants such as Indian mustard and brake ferns can absorb toxic metals such as lead, arsenic, and others and store them in their leaves. Plants can then be recycled or harvested and incinerated.

Trade-Offs

Phytoremediation

Advantages	Disadvantages
Easy to establish	Slow (can take several growing seasons)
Inexpensive	Effective only at depth plant roots can reach
Can reduce material dumped into landfills	Some toxic organic chemicals may evaporate from plant leaves
Produces little air pollution compared to incineration	Some plants can become toxic to animals
Low energy use	

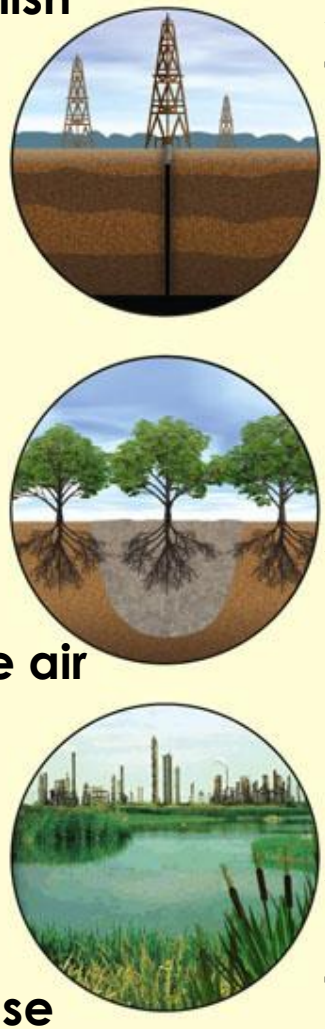


Fig. 22-18, p. 538

Conversion to Less Hazardous Substances

- ***Incineration***: heating many types of hazardous waste to high temperatures – up to 2000 °C – in an incinerator can break them down and convert them to less harmful or harmless chemicals.

Conversion to Less Hazardous Substances

- ***Plasma Torch***: passing electrical current through gas to generate an electric arc and very high temperatures can create plasma.
  - The plasma process can be carried out in a torch which can decompose liquid or solid hazardous organic material.

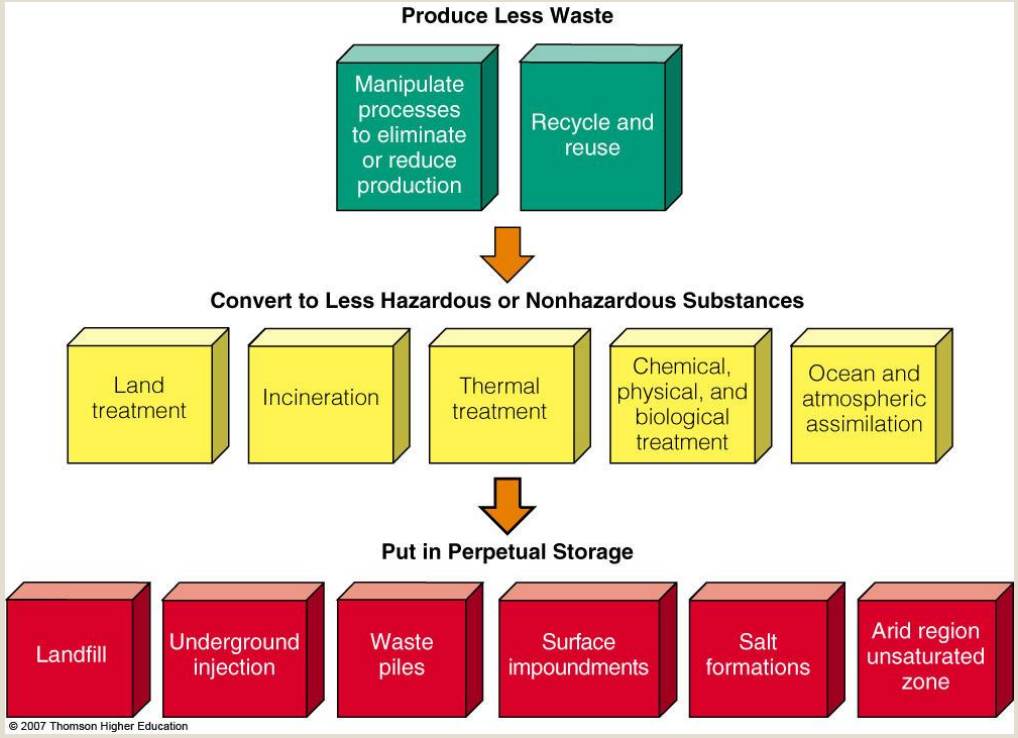
Trade-Offs

Plasma Arc

Advantages	Disadvantages
Small	High cost
	Produces CO2 and CO
Mobile. Easy to move to different sites	Can release particulates and chlorine gas
Produces no toxic ash	Can vaporize and release toxic metals and radioactive elements

Fig. 22-19, p. 538

DEALING WITH HAZARDOUS WASTE

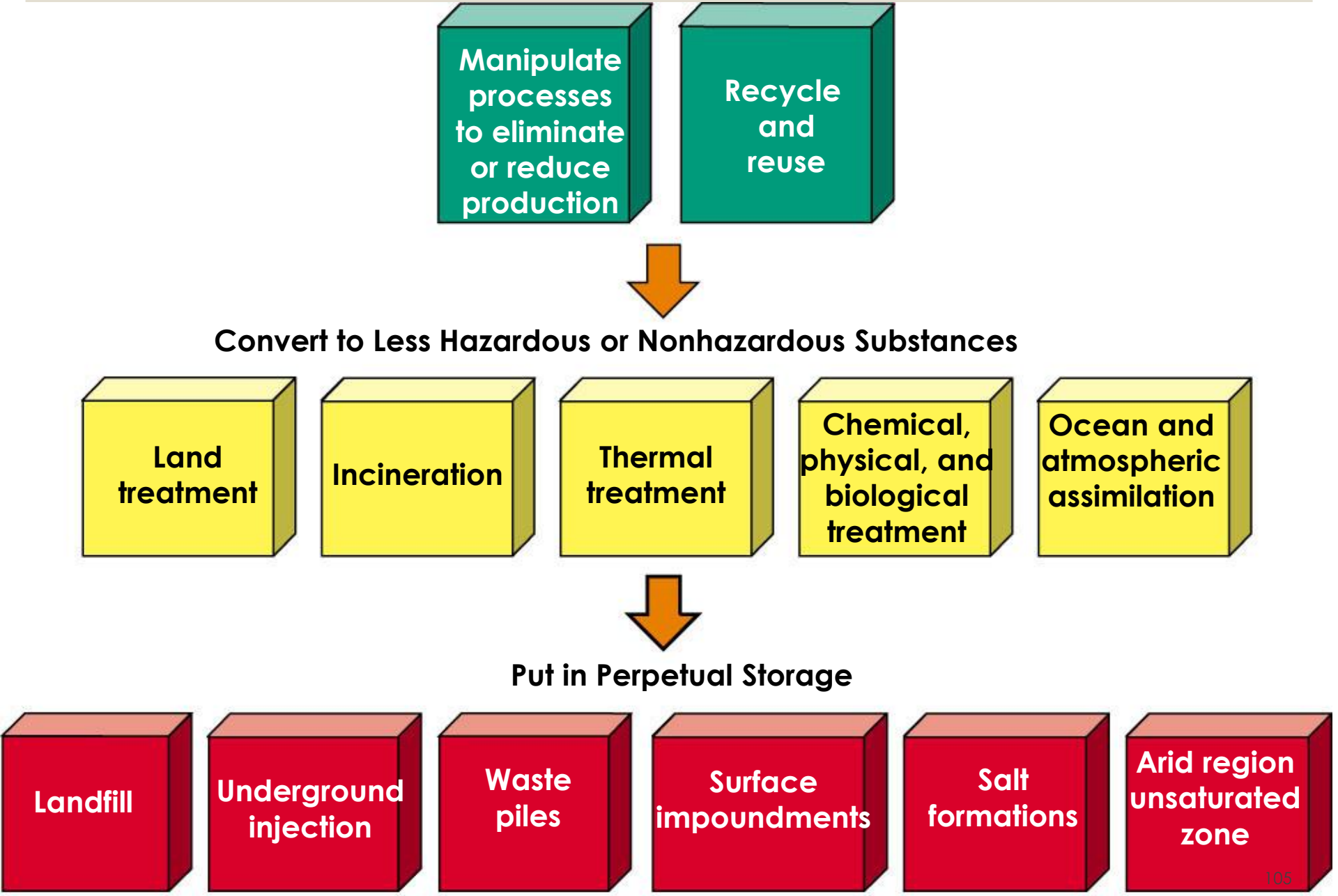


- We can produce less hazardous waste and recycle, reuse, detoxify, burn, and bury what we continue to produce.

Figure 22-16

Produce Less Waste

Fig. 22-16, p. 536



ACHIEVING A LOW-WASTE SOCIETY

- In the U.S., citizens have kept large numbers of incinerators, landfills, and hazardous waste treatment plants from being built in their local areas.
- Environmental justice means that everyone is entitled to protection from environmental hazards without discrimination.

Global Outlook: International Action to Reduce Hazardous Waste

- An international treaty calls for phasing out the use of harmful persistent organic pollutants (POPs).
  - POPs are insoluble in water and soluble in fat.
  - Nearly every person on earth has detectable levels of POPs in their blood.
  - The U.S has not ratified this treaty.

Making the Transition to a Low-Waste Society: A New Vision

- Everything is connected.
- There is no "away" for the wastes we produce.
- Dilution is not always the solution to pollution.
- The best and cheapest way to deal with wastes are reduction and pollution prevention.